



(11) **EP 1 273 937 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.01.2003 Bulletin 2003/02

(51) Int Cl.7: **G02B 6/16, C03B 37/075,
G02B 6/12**

(21) Application number: **01202513.6**

(22) Date of filing: **29.06.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

- **Socci, Luciano**
20126 Milano (IT)
- **Romagnoli, Marco**
20100 Milano (IT)

(71) Applicant: **PIRELLI CAVI E SISTEMI S.p.A.**
20126 Milano (IT)

(74) Representative: **Bottero, Claudio et al**
Porta, Checcacci & Associati S.p.A.
Viale Sabotino, 19/2
20135 Milano (IT)

(72) Inventors:
• **Gorni, Giacomo**
27100 Pavia (IT)

(54) **Unit for compensating the chromatic dispersion in a reconfigurable manner**

(57) Unit (100) comprising a portion of holey optical fibre (12) having a length L_c comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective

diameter and being spaced, two by two, according to a respective pitch, said unit comprising also a temperature adjusting device (16) for bringing and maintaining the holey optical fibre (12) at temperature values T selectable in a predetermined interval of temperatures T_x - T_y .

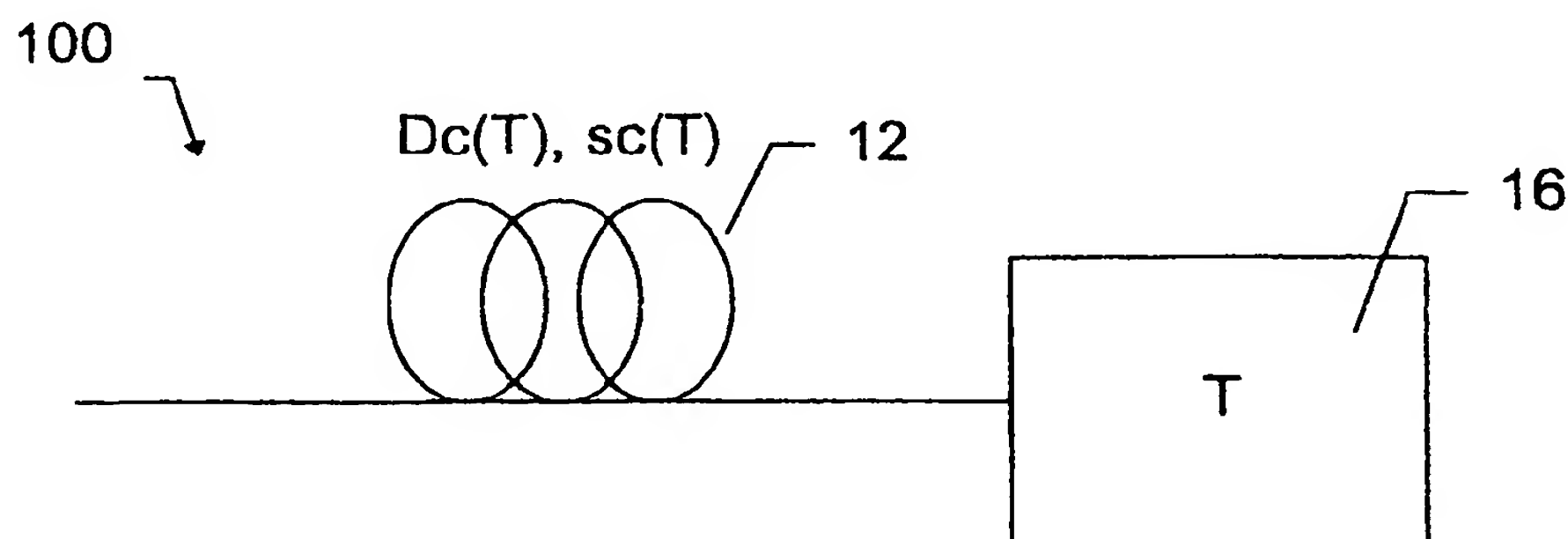


Fig. 3a

Description

[0001] The present invention relates to a reconfigurable unit for compensating the chromatic dispersion, and optionally, the chromatic dispersion slope, comprising a holey optical fibre and a temperature adjusting device.

[0002] Moreover, the present invention relates to an optical communication line and an optical communication system comprising such unit, and a method for compensating chromatic dispersion, and optionally, the chromatic dispersion slope, in a reconfigurable manner.

[0003] In the present description and claims, the expression:

* "chromatic dispersion coefficient D" is used to indicate the dependence at the first order of group velocity on the wavelength. More in particular, the chromatic dispersion coefficient D is expressed by the following relation (Govind P. Agrawal, "Nonlinear Fiber Optics - Second Edition", Academic Press, pages 8-10)

$$D = \frac{d\beta_1}{d\lambda} = -\frac{2\pi c}{\lambda^2} \beta_2$$

where β_1 and β_2 are the propagation constants of the first and second order, respectively, and D is expressed in ps/(nm*Km). Moreover, the chromatic dispersion coefficient D can have a positive or negative value based on the sign of the propagation constant β_2 ;

* "chromatic dispersion D*L" is used to indicate the chromatic dispersion, expressed in ps/nm, accumulated along an optical transmission fibre having a chromatic dispersion coefficient D, expressed in ps/(nm*Km), and a length L, expressed in Km (such product D*L can have a positive or negative value according to whether the chromatic dispersion coefficient D is positive or negative);

* "chromatic dispersion slope s" is used to indicate the derivative, with respect to the wavelength, of the chromatic dispersion coefficient D, is expressed in ps/(nm²*Km) and can have a positive or negative value; and

* "optical transmission fibre" is used to indicate an optical fibre used in an optical communication line or system for transmitting optical signals from a point to the other, located at a considerable distance (for example, at at least some km or tenths of km).

[0004] In the field of optical telecommunications and optical signal propagation in an optical transmission fibre, chromatic dispersion (or second order dispersion), defined by the above chromatic dispersion coefficient D, is a phenomenon for which different spectral components of a light pulse propagating in an optical fibre travel at different speeds, causing a temporal broadening of the pulse.

[0005] In an optical communication system, chromatic dispersion thus limits the maximum data transmission speed (that is, the bit rate) or the maximum connection length without electrical signal regeneration.

[0006] In order to compensate chromatic dispersion $D_t \cdot L_t$ accumulated along an optical transmission fibre having a chromatic dispersion coefficient D_t and a length L_t , there are known devices comprising, for example, an optical fibre specifically designed to have a very high value of the chromatic dispersion coefficient D_c , with opposed sign with respect to that of the optical transmission fibre, and such length L_c as to satisfy the relation $D_t \cdot L_t = -D_c \cdot L_c$.

[0007] However, a compensator device of this type, designed so as to compensate a certain value of chromatic dispersion $D_t \cdot L_t$, is not suitable for compensating the chromatic dispersion of another optical transmission fibre characterised by a different value of product $D_t \cdot L_t$ with respect to that for which the compensator device has been designed.

[0008] For example, a compensator device designed to compensate exactly the chromatic dispersion accumulated along a span of 100 Km ($L_t = 100$ Km) of a conventional single mode optical fibre (or SMF) having a value of the chromatic dispersion coefficient D_t equal to about 17 ps/(nm*Km) is not capable of compensating exactly the chromatic dispersion of spans of the same SMF fibre having, however, a length different from 100 Km (for example, 70, 80, 90 or 110 Km).

[0009] Moreover, a compensator device designed to compensate exactly the chromatic dispersion accumulated along a span of 100 Km of a conventional SMF fibre is not capable of compensating exactly the chromatic dispersion accumulated along such span of 100 km in case of variations of the chromatic dispersion coefficient D_t of the SMF fibre with respect to the nominal value due, for example, to the variation of system parameters, such as temperature.

[0010] Even though in this latter case the variation of the value of chromatic dispersion $D_t \cdot L_t$ of the optical transmission fibre generally is irrelevant in an optical communication system with moderate bit rates, it becomes very important at high bit rates (2,5, 10, 40, 80 Gbit/s), at which an increasingly higher precision of the chromatic dispersion compensation is required.

[0011] There is thus the need for a unit for compensating the chromatic dispersion, suitable to be reconfigured so as to compensate, according to requirements, different values of chromatic dispersion $D_t \cdot L_t$ accumulated along an optical transmission fibre.

[0012] B.J. Eggleton et al. ("*Tunable dispersion compensation in a 160-Gb/s TDM system by a voltage controlled chirped fiber Bragg grating*", IEEE Photonics Technology Letters, Vol. 12, No. 8, August 2000, pages 1022-1024) describe an integrated chirp-tunable Bragg grating for compensating chromatic dispersion in a dynamic manner and capable of recovering 2 ps pulses over a 50 ps/nm tuning interval, with a system penalty that is less than 1.3 dB.

[0013] S.T. Vohra et al ("*Dynamic dispersion compensation using bandwidth tunable fiber Bragg gratings*", ECOC 2000) describe a device for compensating chromatic dispersion in a tunable manner, realised with a fibre Bragg grating and capable of compensating chromatic dispersion in a tuning interval from -150 ps/nm to -3500 ps/nm.

[0014] However, the above devices are not capable of compensating also the third order dispersion or chromatic dispersion slope (or slope) according to which light pulses at different wavelength propagate in an optical fibre with different dispersions.

[0015] This phenomenon, caused by the chromatic dispersion being a phenomenon depending on the wavelength, is a problem in wavelength division multiplexing (or WDM) optical communication systems, where information is carried along the same optical fibre by a plurality of optical signals at different wavelength.

[0016] Thus, in WDM optical communication systems, it is necessary to compensate not only chromatic dispersion but also chromatic dispersion slope in the interval of wavelengths of interest.

[0017] Devices for compensating both chromatic dispersion and chromatic dispersion slope of a conventional single mode fibre (or SMF) are known.

[0018] For example, to compensate both a chromatic dispersion coefficient D_t and a chromatic dispersion slope s_t , there are known devices comprising an optical fibre specifically designed to have very high values of the chromatic dispersion coefficient D_c and of chromatic dispersion slope s_c , with opposed sign with respect to those of the SMF optical fibre of which dispersion is to be compensated, so that relation $D_t/s_t = D_c/s_c$ is satisfied (T. Kashiwada et al., "*Broadband dispersion compensating module considering its attenuation spectrum behavior for WDM system*", OFC '99, WM12, pages 229-231; G.E. Berkey et al., "*Negative slope dispersion compensating fibers*", OFC '99, WM14, pages 235-237 and L. Gruner-Nielsen et al., "*Design and manufacture of dispersion compensating fibre for simultaneous compensation of dispersion and dispersion slope*", OFC '99, Technical Digest WM13, pages 232-234).

[0019] In fact, it is known that both the following relations must be satisfied for compensating both the chromatic dispersion coefficient D_t and the chromatic dispersion slope s_t

$$D_t \cdot L_t + D_c \cdot L_c = 0$$

$$s_t \cdot L_t + s_c \cdot L_c = 0$$

that is, the D_t/s_t ratio must be equal to the D_c/s_c ratio.

[0020] Moreover, the dispersive properties of a holey optical fibre have been studied in recent years.

[0021] A holey optical fibre typically consists of a single material in which the refractive index difference between core and cladding, which allows guided propagation, is obtained through the presence of holes in the cladding, which lower the refractive index of the material forming the fibre.

[0022] More in particular, a holey optical fibre has a cladding region comprising holes that run along the entire fibre length, and a solid core region determined by the absence of at least one hole in the material.

[0023] For example, US 5 802 236 patent describes a micro-structured optical fibre which includes a solid silica core region surrounded by a inner cladding region and an outer cladding region. The cladding region has capillary holes that extend in the axial direction of the fibre. The holes in the outer cladding region are of a smaller diameter than the holes in the inner cladding region and therefore the effective refractive index of the outer cladding region is greater than the effective refractive index of the inner cladding region. This document states that this type of fibre may have high negative values of the chromatic dispersion coefficient D (for example, values that are more negative than -300 ps/nm·Km) at a predetermined wavelength (for example, 1550 nm) and high negative values of the chromatic dispersion slope s so that the fibre can carry out a dispersion compensation in a range of wavelengths of 20 nm or more.

[0024] However, the above devices suitable for compensating both chromatic dispersion and chromatic dispersion slope of a conventional single mode fibre are not reconfigurable.

[0025] The Applicant has posed the technical problem of compensating both chromatic dispersion and chromatic dispersion slope in a reconfigurable manner.

[0026] More in general, the Applicant has posed the technical problem of compensating the chromatic dispersion in a reconfigurable manner.

[0027] The Applicant has found that the above technical problems can be solved by a unit comprising a holey optical fibre and a device for adjusting the temperature thereof in a predetermined interval of temperatures.

[0028] In fact, observing that the chromatic dispersion coefficient D_c and the chromatic dispersion slope s_c of a holey optical fibre vary as the temperature varies, the Applicant has found that a holey optical fibre having length L_c can be used to obtain, as the temperature varies, desired values of chromatic dispersion $D_c(T) \cdot L_c$ and of the $D_c(T)/s_c(T)$ ratio.

[0029] In a first aspect thereof, therefore, the present invention relates to a unit comprising a portion of holey optical fibre having a length L_c comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch, said unit being characterised in that it also comprises a temperature adjusting device for bringing and maintaining the holey optical fibre at temperature values T selectable in a predetermined interval of temperatures T_x - T_y .

[0030] In the present description and claims, the term "pitch" is used to indicate the centre-centre distance between two adjacent holes of a holey optical fibre.

[0031] Typically, the core region of the holey optical fibre portion is solid.

[0032] Advantageously, for compensating chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values, in a reconfigurable manner at a preselected wavelength λ , the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y are selected so that at the preselected wavelength λ , the holey optical fibre has such values of the chromatic dispersion coefficient $D_c(T)$ in function of temperature that, as temperature T varies between value T_x and value T_y , the following relation $D_t \cdot L_t = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in said predetermined interval of values.

[0033] This advantageously allows compensating, in a reconfigurable manner, and with a single unit, different values of chromatic dispersion $D_t \cdot L_t$ comprised in a predetermined interval of values.

[0034] Typically, the diameter and pitch of the holes of the holey optical fibre are selected so that the chromatic dispersion coefficient $D_c(T)$ of the holey fibre is negative. This allows compensating the chromatic dispersion of conventional optical transmission fibres - having a positive chromatic dispersion coefficient D_t - such as, for example, SMF optical fibres produced, for example, by FOS or by CORNING Inc.; True Wave™ (TW), True Wave Plus™ (TW+) or True Wave RS™ (TW RS) optical fibres produced by LUCENT Technology Inc.; large effective area (or LEAF) or LEAF Enhanced optical fibres produced by CORNING Inc., and FreeLight™ optical fibres produced by FOS.

[0035] Advantageously, the chromatic dispersion coefficient $D_c(T)$ of the holey optical fibre is negative as temperature T varies between value T_x and value T_y .

[0036] Typically, the cladding region of the holey optical fibre portion comprises a first ring of holes around the core region.

[0037] Such ring of holes can have any shape. Typically, it has a hexagonal shape. In general, it has a circular symmetry.

[0038] Advantageously, the ratio between the area taken by the first ring holes and the total area of the circular crown defined by said first ring of holes is more than 0.5. Preferably, said ratio is more than 0.6. More preferably, it is more than 0.7. In fact, the Applicant has found that the variation, as temperature changes, of the chromatic dispersion coefficient $D_c(T)$ of the holey optical fibre increases as said ratio increases.

[0039] Typically, the holes of said first ring have a mean diameter d and are spaced from one another by a mean pitch Λ .

[0040] Preferably, the d/Λ ratio is more than 0.7. Preferably, it is more than 0.8. More preferably, it is more than 0.9. In fact, the Applicant has found that the variation, as temperature changes, of the chromatic dispersion coefficient $D_c(T)$ of the holey optical fibre increases as the d/Λ ratio increases.

[0041] Moreover, as described in the European patent application number 00830495.8, filed by the Applicant, the mean pitch Λ of the holes of said first ring is advantageously selected through the following relation (H)

$$\Lambda = \frac{\lambda}{n} \left(\frac{1}{1 + \frac{1}{2} \frac{d}{\Lambda}} \right) \pm 0.25 \text{ } \mu\text{m}$$

where n is the refractive index of the material forming the holey optical fibre core region.

[0042] This makes the holey optical fibre 12 to have a high absolute value of the chromatic dispersion coefficient D_c at wavelength λ .

[0043] The Applicant has noted that relation H agrees with the corresponding values of Λ obtained solving the Maxwell

equations in an interval of wavelengths comprised between 1300 and 1700 nm.

[0044] More in particular, relation

$$\Lambda = \frac{\lambda}{n} \left(\frac{1}{1 + \frac{1}{2} \frac{d}{\Lambda}} \right)$$

provides an optimum approximation (with an error in the range of few nm) of the value of Λ corresponding to a maximum absolute value of D_c around the wavelength of 1550 nm, for a value of d/Λ of at least about 0.7, and for a hexagonal shape of the first ring of holes.

[0045] In an embodiment, all the holes of said first ring substantially have the same diameter. Moreover, said holes are substantially equally spaced from one another. This advantageously allows facilitating the fibre production process.

[0046] Advantageously, the cladding region also comprises at least a second ring of holes arranged around said first ring of holes.

[0047] Said rings of holes can have any shape. Typically, they have a hexagonal shape. In general, they have a circular symmetry.

[0048] In an embodiment, the holes of said first and said at least one second ring substantially have the same mean diameter d and are spaced from one another by the same mean pitch Λ . This advantageously allows facilitating the fibre production process.

[0049] In an alternative embodiment, the holes of said first ring have a mean diameter that is different from the mean diameter of the holes of said at least one second ring.

[0050] Preferably, the holes of said first ring have a greater mean diameter than the mean diameter of the holes of said at least one second ring. In fact, the Applicant has noted that this allows increasing the effective area of the core region of the holey optical fibre.

[0051] Typically, said core region of the holey optical fibre portion is made of a silica-based vitreous material.

[0052] Typically, also said cladding region of the holey optical fibre portion is made of a silica-based vitreous material.

[0053] However, the cladding and core region do not necessarily consist of the same material.

[0054] Typically, the holes defined by the cladding region are filled with air. Alternatively, they are filled with another material having a lower refractive index than that of the material forming the core region. For example, such material is a gas. More in particular, a gas that does not chemically interact with the material of the core and cladding region.

[0055] Advantageously, wavelength λ is comprised between about 1300 nm and 1700 nm. Preferably, it is comprised between about 1450 nm and 1600 nm. More preferably, it is comprised in the third optical fibre transmission band (that is, between about 1500 nm and 1600 nm). Even more preferably, it is comprised in the typical transmission band of an erbium-doped optical amplifier (that is, between about 1530 nm and 1600 nm).

[0056] Advantageously, to reduce its volume, the holey optical fibre is wound on itself and contained in a container.

[0057] The temperature adjusting device is thermally connected to said container.

[0058] Preferably, in order to allow a good heat conduction from the temperature adjusting device to the holey optical fibre, the container consists of a good temperature conductor material.

[0059] Advantageously, temperature T_x is less than temperature T_y . Moreover, the interval of temperatures T_x - T_y can be any interval selected in the interval of temperatures comprised between about -20°C and 80°C.

[0060] Typically, temperature T_x is comprised between about -20 and 20 °C.

[0061] Typically, temperature T_y is comprised between about 20 and 80 °C.

[0062] Moreover, the difference between temperature T_y and temperature T_x typically is of at least about 30°C.

[0063] To compensate a predetermined value of chromatic dispersion slope s_t and a predetermined value of chromatic dispersion $D_t \cdot L_t$, at a preselected wavelength λ and at a preselected temperature T_z comprised in the interval T_x - T_y , the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y are selected so that at the preselected wavelength λ , the holey optical fibre has such values of the chromatic dispersion slope $s_c(T)$ and values of the chromatic dispersion coefficient $D_c(T)$ in function of the temperature, as to satisfy the following relations at temperature T_z

$$D_t/s_t = D_c(T_z)/s_c(T_z) \text{ and } D_t \cdot L_t = - D_c(T_z) \cdot L_c.$$

[0064] Typically, the diameter and pitch of the holes of the holey optical fibre are selected so that also the chromatic

dispersion slope sc of the holey fibre is negative. This allows compensating also the chromatic dispersion slope of conventional optical transmission fibres - having a positive chromatic dispersion slope st - such as, for example, the above SMF, True Wave™, True Wave Plus™, True Wave RS™, LEAF, LEAF Enhanced and FreeLight™ optical fibres.

[0065] Advantageously, the chromatic dispersion slope $sc(T)$ of the holey optical fibre is negative as temperature T varies between value T_x and value T_y .

[0066] Typically, said ring of holes around the core region of the holey optical fibre substantially defines, around the core region, a circular crown having an inside radius r_1 and an outside radius r_2 whose values are selected so as to substantially satisfy the following relation (L)

$$r_1 \leq \lambda/n \leq r_2$$

where n is the refractive index of the material forming the holey optical fibre core region.

[0067] As described in the European patent application number 00830495.8, the Applicant has, in fact, found that a holey optical fibre, in which the first ring of holes defines a circular crown having such radii r_1 and r_2 that wavelength λ/n is comprised between values r_1 and r_2 , exhibits a negative chromatic dispersion slope sc .

[0068] Advantageously, the mean pitch value Λ substantially satisfies the following relation (C)

$$\frac{\lambda}{n} * \frac{1}{1 + \frac{1}{2} \left(\frac{d}{\Lambda} \right)} \leq \Lambda \leq \frac{\lambda}{n} * \frac{1}{1 - \frac{1}{2} \left(\frac{d}{\Lambda} \right)}$$

[0069] In fact, the Applicant has found that the above relation (L) is satisfied when the mean pitch Λ substantially satisfies the following relation (C).

[0070] In a preferred embodiment, the unit also comprises a second portion of holey optical fibre having a predetermined length L_c' comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch.

[0071] In this case, the temperature adjusting device is also advantageously suitable for bringing and maintaining the second holey optical fibre at temperature values T' selectable in a second, predetermined interval of temperatures $T_x'-T_y'$.

[0072] The Applicant has found that the unit according to this embodiment, having two holey optical fibres, has the necessary flexibility to be engineered for compensating not only chromatic dispersion values $D_t * L_t$ comprised in a predetermined interval of values, but also a predetermined ratio D_t/st , as temperatures T and T' vary, in a predetermined manner, in the intervals of temperatures T_x-T_y and $T_x'-T_y'$.

[0073] Typically, the core region of the second holey optical fibre portion is solid.

[0074] Advantageously, for compensating chromatic dispersion values $D_t * L_t$ comprised in a predetermined interval of values, in a reconfigurable manner at the preselected wavelength λ , the hole diameter and pitch, the lengths L_c and L_c' , and the intervals of temperature T_x-T_y and $T_x'-T_y'$ are advantageously selected so that at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$, in function of temperature that, as temperatures T , T' vary, in a predetermined manner, between value T_x and value T_y , and respectively, between value T_x' and T_y' , the following relation (K) is substantially satisfied

$$D_t * L_t = - [D_c(T) * L_c + D_c(T') * L_c']$$

for all values of chromatic dispersion $D_t * L_t$ comprised in said predetermined interval of values.

[0075] To compensate also a predetermined ratio D_t/st between the chromatic dispersion coefficient D_t and a chromatic dispersion slope st , at the preselected wavelength λ and as temperatures T , T' vary, the hole diameter and pitch of the first and second holey fibre, the lengths L_c and L_c' and the intervals of temperature T_x-T_y and $T_x'-T_y'$ are also advantageously selected so that, at the preselected wavelength λ , the first and the second holey optical fibres have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$ in function of temperatures T and T' that, as temperatures T , T' vary in said predetermined manner between value T_x and value T_y and, respectively, between value T_x' and value T_y' , also the

following relation (J) is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{Dc(T)}{sc(T)} \cdot Lc + \frac{Dc(T')}{sc(T')} \cdot Lc'}{Lc + Lc'}$$

[0076] This last embodiment of the invention advantageously allows compensating not only chromatic dispersion values $Dt \cdot Lt$ comprised in a predetermined interval of values, but also a predetermined ratio Dt/st , as temperatures T and T' vary, in a predetermined manner, in the intervals of temperatures T_x - T_y and T_x' - T_y' .

[0077] In other words, this last embodiment allows compensating both the chromatic dispersion slope and the chromatic dispersion coefficient of optical transmission fibres having the same values of chromatic dispersion slope st and of chromatic dispersion coefficient Dt but different lengths Lt (that is, having equal values of the Dt/st ratio but different chromatic dispersion values $Dt \cdot Lt$).

[0078] For compensating also values of the Dt/st ratio comprised in a preselected interval of values, at the preselected wavelength λ and as temperatures T , T' vary, besides chromatic dispersion values $Dt \cdot Lt$ comprised in a predetermined interval of values, the hole diameter and pitch of the first and second holey fibre, the lengths Lc and Lc' and the intervals of temperature T_x - T_y and T_x' - T_y' are also advantageously selected so that, at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and values of the chromatic dispersion coefficient $Dc(T)$ and, respectively, $Dc(T')$ in function of temperatures T and T' that, as temperatures T , T' vary in a predetermined manner between value T_x and value T_y and, respectively, between value T_x' and value T_y' , also the following relation (J) is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{Dc(T)}{sc(T)} \cdot Lc + \frac{Dc(T')}{sc(T')} \cdot Lc'}{Lc + Lc'}$$

for all values of the Dt/st ratio comprised in said preselected interval of values.

[0079] This last embodiment of the invention advantageously allows compensating not only chromatic dispersion values $Dt \cdot Lt$ comprised in a predetermined interval of values, but values of the Dt/st ratio comprised in a preselected interval of values, as temperatures T and T' vary, in a predetermined manner, in the intervals of temperatures T_x - T_y and T_x' - T_y' .

[0080] In other words, this last embodiment allows compensating both the chromatic dispersion slope and the chromatic dispersion coefficient of an optical transmission fibre having a fixed length Lt but variable values of chromatic dispersion slope st and of chromatic dispersion coefficient Dt with respect to the nominal value (due, for example, to variations of system parameters, such as temperature).

[0081] Typically, the cladding region of the second holey optical fibre defines a first ring of holes around the core region. Moreover, the holes of said first ring have a mean diameter d' and are spaced from one another by a mean pitch Λ' .

[0082] Moreover, the d/Λ ratio of the first holey optical fibre and the d'/Λ' ratio of the second holey optical fibre are advantageously different from each another.

[0083] In this way, the chromatic dispersion coefficients $Dc(T)$ and $Dc(T')$ of the two portions of holey optical fibre vary in a different way as the temperature varies.

[0084] Advantageously, ratio d/Λ of the first holey optical fibre is of at least 0.7. Preferably, it is of at least 0.8. More preferably, it is of at least 0.9.

[0085] Advantageously, ratio d'/Λ' of the second holey optical fibre is comprised between 0.4 and 0.7. Preferably, it is comprised between 0.4 and 0.6.

[0086] Moreover, in the unit with two portions of optical fibre, the temperature adjusting device can consist of two temperature adjusting apparatuses, one for bringing and maintaining the first holey optical fibre at temperature values selectable in the first predetermined interval of temperatures T_x - T_y and the other for bringing and maintaining the second holey optical fibre at temperature values selectable in the second predetermined interval of temperatures T_x' - T_y' .

[0087] In a second aspect thereof, the present invention further relates to an optical communication line comprising

- * a portion of optical transmission fibre having a length Lt and a chromatic dispersion coefficient Dt at a wavelength λ ; and
- * a unit comprising, in turn, a portion of holey optical fibre having a predetermined length Lc and comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch,

characterised in that

- said unit also comprises a temperature adjusting device for bringing and maintaining the holey optical fibre at a temperature value T_z selectable in a predetermined interval of temperatures T_x - T_y ; and in that
- the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the holey optical fibre has such value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , as to compensate the chromatic dispersion of the optical transmission fibre portion.

[0088] Typically, the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the chromatic dispersion coefficient $D_c(T_z)$ has such value as to substantially satisfy the following relation $D_t \cdot L_t = - D_c(T_z) \cdot L_c$.

[0089] Typically, in said optical communication line

- the portion of optical transmission fibre also has a chromatic dispersion slope s_t at wavelength λ , and
- in the unit, the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperature T_x - T_y are also selected so that the holey optical fibre has such value of the chromatic dispersion slope $s_c(T_z)$ and a value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , that also the following relation $D_t/s_t = D_c(T_z)/s_c(T_z)$ is substantially satisfied, so as to substantially compensate also the chromatic dispersion slope of the optical transmission fibre portion.

[0090] In the event that the portion of optical transmission fibre has a variable chromatic dispersion $D_t \cdot L_t$ in a predetermined interval of values, the hole diameter and pitch, the length L_c and the interval of temperatures T_x - T_y are also advantageously selected so that at the preselected wavelength λ , the holey optical fibre has such values of the chromatic dispersion coefficient $D_c(T)$ in function of temperature that, as temperature T varies between value T_x and value T_y , the following relation $D_t \cdot L_t = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in said predetermined interval of values.

[0091] Preferably, the unit also comprises a second portion of holey optical fibre having a predetermined length L_c' comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch.

[0092] In this case, the temperature adjusting device is also advantageously suitable for bringing and maintaining the second holey optical fibre at a temperature value T_z' selectable in a second, predetermined interval of temperatures T_x' - T_y' .

[0093] For compensating the chromatic dispersion $D_t \cdot L_t$ of the optical transmission fibre portion, the hole diameter and pitch of the first and second holey fibre, the lengths L_c and L_c' , the values of temperature T_z and T_z' and the intervals of temperature T_x - T_y and T_x' - T_y' are advantageously selected so that at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion coefficient $D_c(T_z)$ and, respectively, $D_c(T_z')$ that the following relation is substantially satisfied

$$D_t \cdot L_t = - [D_c(T_z) \cdot L_c + D_c(T_z') \cdot L_c'].$$

[0094] For compensating also the chromatic dispersion slope s_t of the optical transmission fibre portion, the hole diameter and pitch of the first and second holey fibre, the lengths L_c and L_c' , the values of temperature T_z and T_z' and the intervals of temperature T_x - T_y and T_x' - T_y' are also advantageously selected so that at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion slope $s_c(T_z)$ and, respectively, $s_c(T_z')$, and values of the chromatic dispersion coefficient $D_c(T_z)$ and, respectively, $D_c(T_z')$, that also the following relation is substantially satisfied

$$\frac{D_t}{s_t} = \frac{\frac{D_c(T_z)}{s_c(T_z)} \cdot L_c + \frac{D_c(T_z')}{s_c(T_z')} \cdot L_c'}{L_c + L_c'}.$$

[0095] In the event that the optical transmission fibre portion has a variable chromatic dispersion $D_t \cdot L_t$ in a predetermined interval of values, the hole diameter and pitch of the first and second holey fibre, the lengths L_c and L_c' , and the intervals of temperature T_x - T_y and T_x' - T_y' are advantageously selected so that at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion coefficient $D_c(T)$ and, respec-

tively, $D_c(T')$, as temperatures T, T' vary, in a predetermined manner, between values T_x and T_y , and respectively, T_x' and T_y' , that the following relation (K) is substantially satisfied

$$D_t \cdot L_t = - [D_c(T) \cdot L_c + D_c(T') \cdot L_c']$$

for all values of chromatic dispersion $D_t \cdot L_t$ comprised in the predetermined interval of values.

[0096] Moreover, if the optical transmission fibre portion also has a variable D_t/st ratio in a preselected interval of values, the hole diameter and pitch of the first and second holey fibre, the lengths L_c and L_c' and the intervals of temperature T_x-T_y and $T_x'-T_y'$ are also selected so that, at the preselected wavelength λ , the first and the second holey optical fibres have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$ that, as temperatures T, T' vary in said predetermined manner between value T_x and value T_y and, respectively, between value T_x' and value T_y' , also the following relation (J) is substantially satisfied

$$\frac{D_t}{st} = \frac{\frac{D_c(T)}{sc(T)} \cdot L_c + \frac{D_c(T')}{sc(T')} \cdot L_c'}{L_c + L_c'}$$

for all values of the D_t/st ratio comprised in said preselected interval of values.

[0097] In general, as regards the features of the unit, of the first and second holey optical fibre portion, of the holes of cladding regions, and of the temperature adjusting device, reference shall be made to what already described with reference to the unit according to the first aspect of the invention.

[0098] The portion of holey optical fibre can be arranged inside, upstream or downstream of said optical transmission fibre portion. Advantageously, it is arranged downstream of said optical transmission fibre portion. This allows limiting the non-linear effects of the holey optical fibre since, in this case, an optical signal in input to such fibre has a relatively low optical power due to the attenuation undergone along the upstream optical transmission fibre portion.

[0099] Typically, said optical communication line also comprises an optical amplifier.

[0100] Preferably, said optical amplifier is arranged downstream of said holey optical fibre portion. This allows amplifying the optical signal after passing along the holey optical fibre, so that, when in input to the holey optical fibre, it has a relatively low optical power due to the attenuation undergone along the optical transmission fibre portion. In this way, non-linear effects on the signal by the holey optical fibre are limited.

[0101] Advantageously, said amplifier is of the active optical fibre type, doped with a rare earth.

[0102] Typically, said rare earth is erbium.

[0103] Typically, said portion of optical transmission line is a conventional optical fibre essentially consisting of a core and a cladding having a lower refractive index than that of the core, so as to confine the transmitted signal into the latter.

[0104] Typically, both the core and the cladding are made of a silica-based vitreous material, and the difference of refractive index between core and cladding is obtained by incorporating suitable dopants (such as, for example, germanium, phosphorus and/or fluorine) in the vitreous matrix of the core and/or cladding.

[0105] Typically, said optical transmission fibre portion is a conventional single mode optical fibre (or SMF) produced, for example, by FOS or by CORNING Inc..

[0106] Advantageously, said optical transmission fibre portion is selected from the group comprising a True Wave™ (TW) optical fibre, a True Wave Plus™ (TW+) optical fibre, a True Wave RS™ (TW RS) optical fibre produced by LUCENT Technology Inc.; a large effective area optical fibre (or LEAF), a LEAF Enhanced optical fibre produced by CORNING Inc., and a FreeLight™ optical fibre produced by FOS.

[0107] In a third aspect thereof, the present invention further relates to an optical communication system comprising

- * a transmitting suitable for providing an optical signal having a signal wavelength λ ;
- * an optical communication line, optically connected to said transmitting station, for transmitting said optical signal, said line comprising at least one portion of optical transmission fibre, having a length L_t and a chromatic dispersion coefficient D_t at wavelength λ , and a unit comprising, in turn, a portion of holey optical fibre having a predetermined length L_c and comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch,
- * a receiving station, optically connected to said optical communication line, for receiving said optical signal,

characterised in that

- said unit also comprises a temperature adjusting device for bringing and maintaining the holey optical fibre at a temperature value T_z selectable in a predetermined interval of temperatures T_x - T_y ; and in that
- the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the holey optical fibre has such value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , as to compensate the chromatic dispersion of the optical transmission fibre portion.

[0108] In general, as regards the features of the optical communication line and of the unit, reference shall be made to what already described with reference to the first and second aspect of the invention.

[0109] Typically, said optical signal is a WDM optical signal comprising a plurality of N signals having wavelengths $\lambda_1, \lambda_2, \dots, \lambda_N$.

[0110] In a further aspect thereof, the present invention also relates to a use, for compensating the chromatic dispersion in a reconfigurable manner, of a unit comprising a portion of holey optical fibre having a length L_c comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch, said unit being characterised in that it also comprises a temperature adjusting device for bringing and maintaining the holey optical fibre at temperature values T selectable in a predetermined interval of temperatures T_x - T_y so that the holey optical fibre takes desired chromatic dispersion values $D_c(T)$.

[0111] As regards the features of the unit, reference shall be made to what described above with reference to the first aspect of the invention.

[0112] In a further aspect thereof, the present invention also relates to a method for compensating chromatic dispersion in a reconfigurable manner, comprising the steps of

a) providing a holey optical fibre having a length L_c and comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch;

b) bringing and maintaining said holey optical fibre at a temperature T selectable in a predetermined interval of temperatures T_x - T_y so that the holey optical fibre has a desired chromatic dispersion value $D_c(T)$.

[0113] Advantageously, for compensating chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values, in a reconfigurable manner at a preselected wavelength λ , the method also comprises the step c) of selecting the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y so that at the preselected wavelength λ , the holey optical fibre has such values of the chromatic dispersion coefficient $D_c(T)$ in function of temperature that, as temperature T varies between value T_x and value T_y , the following relation $D_t \cdot L_t = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in said predetermined interval of values.

[0114] To compensate both a predetermined value of chromatic dispersion slope s_t and a predetermined value of chromatic dispersion D_t , at a preselected wavelength λ and at a preselected temperature T_z comprised in the interval T_x - T_y , the method of the invention also comprises the step d) of selecting the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y so that at the preselected wavelength λ , the holey optical fibre has such value of the chromatic dispersion slope s_c and such value of the chromatic dispersion coefficient D_c in function of the temperature, as to substantially satisfy the following relation $D_t/s_t = D_c(T_z)/s_c(T_z)$.

[0115] In a preferred embodiment, the method of the invention also comprises the step e) of providing also a second portion of holey optical fibre having a predetermined length L_c' comprising a core region and a cladding region, said cladding region comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch.

[0116] In this case, the method of the invention also comprises the step f) of bringing and maintaining the second holey optical fibre at a temperature value T' selectable in a second, predetermined interval of temperatures T_x' - T_y' .

[0117] For compensating chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values, at the preselected wavelength λ , in place of step c) the method of the invention comprises the step g) of selecting the diameter and pitch of the holes of the first and second holey fibre, the lengths L_c and L_c' , and the intervals of temperature T_x - T_y and T_x' - T_y' so that at the preselected wavelength λ , the first and the second holey optical fibre have such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$, in function of temperature that, as temperatures T, T' vary, in a predetermined manner, between value T_x and value T_y , and respectively, between value T_x' and T_y' , the following relation (K) is substantially satisfied

$$D_t \cdot L_t = - [D_c(T) \cdot L_c + D_c(T') \cdot L_c']$$

for all values of chromatic dispersion $Dt \cdot Lt$ comprised in said predetermined interval of values.

[0118] To compensate also a predetermined ratio Dt/st at the preselected wavelength λ and as temperatures T, T' vary, in place of step d) the method of the invention also comprises the step h) of selecting the hole diameter and pitch of the first and second holey fibre, the lengths Lc and Lc' and the intervals of temperature $Tx-Ty$ and $Tx'-Ty'$ so that, at the preselected wavelength λ , the first and the second holey optical fibres have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and values of the chromatic dispersion coefficient $Dc(T)$ and, respectively, $Dc(T')$ in function of temperatures T and T' that, as temperatures T, T' vary in said predetermined manner between value Tx and value Ty and, respectively, between value Tx' and value Ty' , also the following relation (J) is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{Dc(T)}{sc(T)} \cdot Lc + \frac{Dc(T')}{sc(T')} \cdot Lc'}{Lc + Lc'}$$

[0119] Further features and advantages of the present invention will appear more clearly from the following detailed description of a preferred embodiment, made with reference to the attached drawings. In such drawings,

- figure 1 shows a schematic representation of a holey optical fibre suitable for being used in a unit according to the invention;
- figure 2 shows a schematic representation of a unit according to the invention;
- figure 3 shows a schematic representation of a first embodiment of a unit according to the invention (figure 3a), of the unit according to the first embodiment wherein the holey optical fibre is inserted into a temperature adjusting device (figure 3b) and of the unit according to the first embodiment wherein the holey optical fibre is arranged on the temperature adjusting device (figure 3c);
- figure 4 shows a schematic representation of a second embodiment of a unit according to the invention;
- figure 5 shows a schematic representation of a first embodiment of an optical communication line according to the invention;
- figure 6 shows a schematic representation of a second embodiment of an optical communication line according to the invention;
- figure 7 shows a schematic representation of an optical communication system according to the invention;
- figure 8 shows a schematic representation of an optical amplifier suitable to be used in the line of figure 6 and in the system of figure 7;
- figure 9 shows the values of the residual chromatic dispersion slope (residual_s) at various lengths Lt of a TW optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 32 (curve A) and in the case of a unit 100 according to the values of table 12 (curve B);
- figure 10 shows the values of the residual chromatic dispersion slope (residual_s) at various lengths Lt of a TW optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 38 (curve A) and in the case of a unit 100 according to the values of table 16 (curve B);
- figure 11 shows the values of the residual chromatic dispersion slope (residual_s) at various lengths Lt of a TW RS optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 41 (curve A) and in the case of a unit 100 according to the values of table 20 (curve B);
- figure 12 shows the values of the residual chromatic dispersion slope (residual_s) at various lengths Lt of an SMF optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 45 (curve A) and in the case of a unit 100 according to the values of table 24 (curve B);

[0120] Figure 2 shows a schematic representation of a unit 100 according to the invention.

[0121] According to a first embodiment, shown in figure 3a, unit 100 comprises a holey optical fibre portion 12 and

a temperature adjusting device 16.

[0122] The portion of holey optical fibre 12 has a length L_c , a solid core region 13 and a cladding region 14 surrounding the core region 13 (figure 1).

[0123] In the embodiment shown in figure 1, the cladding region 14 comprises two rings of holes surrounding the core region 13 and passing through the holey optical fibre portion 12 longitudinally for its entire length.

[0124] The two rings of holes have hexagonal shape. Moreover, the holes of the two rings have a substantially equal diameter d , and are spaced from one another according to a pitch Λ .

[0125] Moreover, both the core region 13 and the cladding region 14 consist of silica-based vitreous material, and the holes are filled with air.

[0126] The holey optical fibre portion 12 can be produced according to a known method, such as for example, that described in patent US 5 802 236.

[0127] The temperature adjusting device 16 is suitable for bringing and maintaining the holey optical fibre 16 at temperature values T selectable in an interval of temperatures T_x - T_y .

[0128] For example, such device 16 is a conventional small furnace suitable to receive inside the holey optical fibre 12. For example, such small furnace is a device produced and marketed by MAZZALY SYSTEMS S.p.A..

[0129] For example, in the embodiment of figure 3b, the holey optical fibre 12 is wound on itself around a coil, and it is arranged inside the temperature adjusting device 16 whereas, in the embodiment of figure 3c, the holey optical fibre 12, wound on itself around the coil, is arranged on the temperature adjusting device 16.

[0130] Length L_c and diameter d and pitch Λ of the holes of the holey optical fibre 12 and the interval of temperatures T_x - T_y , can be selected so that at a preselected wavelength λ , the holey optical fibre 12 has such values of the chromatic dispersion coefficient $D_c(T)$ in function of temperature that, as temperature T varies between value T_x and value T_y , the following relation $D_t \cdot L_t = -D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values.

[0131] This allows compensating, in a reconfigurable manner, different values of chromatic dispersion $D_t \cdot L_t$ comprised in a predetermined interval of values, at the preselected wavelength λ .

[0132] In the following examples, the values of chromatic dispersion coefficients D_t , D_c and of the chromatic dispersion slope s_t , s_c have been determined at wavelength λ of about 1550 nm.

EXAMPLE 1

[0133] The Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km and predetermined values of the chromatic dispersion coefficient D_t .

[0134] For example, in the case of TW+, FreeLight, Leaf Enhanced, Leaf and TW fibres, the chromatic dispersion coefficient D_t has the values shown in table 1.

Table 1

Type of fibre	D_t (ps/(nm*Km))
TW+	4.0
FreeLight	4.2
Leaf Enhanced	4.3
Leaf	3.7
TW	2.4

[0135] 70 - 110 Km portions of said fibres are thus characterised by the chromatic dispersion values $D_t \cdot L_t$ shown in table 2.

Table 2

$D_t \cdot L_t$ (ps/nm)	70 km	80 km	90 km	100 km	110 km
TW+	280	320	360	400	440
FreeLight	294	336	378	420	462
Leaf Enhanced	301	344	387	430	473
Leaf	259	296	333	370	407

Table 2 (continued)

Dt*Lt (ps/nm)	70 km	80 km	90 km	100 km	110 km
TW	168	192	216	240	264

[0136] In this case, length L_c and diameter d and pitch Λ of the holes of the holey optical fibre 12 and the interval of temperature T_x - T_y , must thus be selected so that at a preselected wavelength λ , the holey optical fibre 12 has such values of the chromatic dispersion coefficient $D_c(T)$ in function of temperature that, as temperature T varies between value T_x and value T_y , the following relation $D_t \cdot L_t = -D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised between 168 and 473 (ps/nm).

[0137] Solving the Maxwell vectorial equations of light propagation in a holey optical fibre - as described, for example, by Ferrando et al. ("*Full-vector analysis of realistic photonic crystal fiber*", Optics Letters, Vol. 24, No. 5, March 1999, pages 276-278) and by Silvestre et al. ("*Biorthormal-basis method for the vector description of optical fiber modes*", Journal of Lightwave Technology, Vol. 16, No. 5, May, 1998, pages 923-928) - the Applicant has determined the values of the chromatic dispersion coefficient $D_c(T)$ as temperature T varies in an interval T_x - T_y comprised between -20 and 60°C of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.165 μm . The determined values are shown in Table 3.

Table 3

T°C	$D_c(T)$ (ps/(nm*Km))
-20	-20.1
20	-15.9
60	-11.8

[0138] With two units 100 having two respective holey optical fibres 12 with the above values of d and d/Λ and length L_c respectively of about 14.2 Km and 24.2 Km, it is thus possible to compensate chromatic dispersion values $D_t \cdot L_t$ comprised between 168 and 286 (ps/nm) and, respectively, 286 and 473 (ps/nm), as shown in Table 4.

Table 4

$D_c \cdot L_c$ (ps/nm)	T = -20°C	T = 20°C	T = 60°C
$L_c = 14.2$ km	-286	-225.7	-168
$L_c = 24.2$ km	-487	-384.7	-286

[0139] In brief, with a unit 100 having a holey optical fibre with a ratio d/Λ equal to about 0.9, a pitch Λ equal to about 1.165 μm and a length L_c of about 14.2 Km, it is possible to compensate chromatic dispersion values $D_t \cdot L_t$ comprised between 168 and 286 (ps/nm) as temperature T varies from -20 to 60 °C.

[0140] In turn, with a unit 100 having a holey optical fibre with a ratio d/Λ equal to about 0.9, a pitch Λ equal to about 1.165 μm and a length L_c of about 24.2 Km, it is possible to compensate chromatic dispersion values $D_t \cdot L_t$ comprised between 286 and 487 (ps/nm) as temperature T varies from -20 to 60 °C.

[0141] With just two units 100 it is thus possible to compensate, in a reconfigurable manner, the chromatic dispersion $D_t \cdot L_t$ of optical transmission fibre portions of the TW+, FreeLight, Leaf Enhanced, Leaf and TW type having typical lengths of optical communication systems (comprised between 70 and 110 Km), by regulating the temperature of temperature adjusting devices 16 between -20°C and 60°C.

EXAMPLE 2

[0142] The Applicant has also considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of SMF optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km and a chromatic dispersion coefficient value D_t equal to about 17 ps/(nm*Km).

[0143] Such 70 - 110 Km portions of SMF fibre are characterised by the chromatic dispersion values $D_t \cdot L_t$ shown in table 5.

Table 5

SMF	70 km	80 km	90 km	100 km	110 km
Dt*Lt (ps/nm)	1190	1360	1530	1700	1870

[0144] The chromatic dispersion coefficient values $D_c(T)$ as temperature T of a holey optical fibre 12 having, for example, a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about $1.145\ \mu\text{m}$ varies, are shown in Table 6.

Table 6

T°C	$D_c(T)$ (ps/(nm*Km))
-20	-41.89
20	-37.43
60	-32.97

[0145] With two units 100 having two respective holey optical fibres 12 with the above features and length L_c respectively of about 36,1 Km and 45.85 Km, it is thus possible to compensate chromatic dispersion values D_t*L_t comprised between 1190 and 1512 (ps/nm) and, respectively, 1512 and 1920 (ps/nm), as shown in Table 7.

Table 7

D_c*L_c (ps/nm)	T = -20°C	T = 20°C	T = 60°C
$L_c = 36.1\ \text{km}$	-1512	-1366	-1190
$L_c = 45.85\ \text{km}$	-1920	-1716	-1512

[0146] With just two units 100 it is thus possible to compensate the chromatic dispersion D_t*L_t of optical transmission fibre portions of the SMF type having lengths comprised between about 70 and 113 Km, by regulating the temperature of temperature adjusting devices 16 in an interval T_x - T_y comprised between -20 and 60°C.

EXAMPLE 3

[0147] Finally, the Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of TW RS optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km and a chromatic dispersion coefficient value D_t equal to about $5.7\ \text{ps}/(\text{nm}\cdot\text{km})$.

[0148] Such 70 - 110 Km portions of TW RS fibre are characterised by the chromatic dispersion values D_t*L_t shown in table 8.

Table 8

TW RS	70 km	80 km	90 km	100 km	110 km
D_t*L_t (ps/nm)	399	456	513	570	627

[0149] The chromatic dispersion coefficient values $D_c(T)$ as temperature T of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about $1.145\ \mu\text{m}$ varies, are shown in Table 9.

Table 9

T°C	$D_c(T)$ (ps/(nm*Km))
-20	-41.89
20	-37.43
60	-32.97

[0150] With two units 100 having two respective holey optical fibres 12 with the above features and length L_c respectively of about 12,1 Km and 15.37 Km, it is thus possible to compensate chromatic dispersion values D_t*L_t comprised between 399 and 507 (ps/nm) and, respectively, 507 and 644 (ps/nm), as shown in Table 10.

Table 10

Dc*Lc (ps/nm)	T = -20°C	T = 20°C	T = 60°C
Lc = 12.1 km	-507	-458	-399
Lc = 15.37 km	-644	-575	-507

[0151] With just two units 100 it is thus possible to compensate the chromatic dispersion $Dt \cdot Lt$ of optical transmission fibre portions of the TW RS type having lengths comprised between 70 and 113 Km, by regulating the temperature of temperature adjusting devices 16 in an interval T_x - T_y comprised between -20 and 60°C.

[0152] Length L_c , diameter d and pitch Λ of the holes of the holey optical fibre 12 and the interval of temperature T_x - T_y , can also be selected so that at a preselected wavelength λ , the holey optical fibre 12 has such values of the chromatic dispersion coefficient $D_c(T)$ and of the chromatic dispersion slope $sc(T)$ in function of temperature that,

- as temperature T varies between value T_x and value T_y , the following relation $Dt \cdot Lt = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $Dt \cdot Lt$ comprised in a predetermined interval of values; and
- for a temperature value T_z selected in the interval of values comprised between T_x and T_y , also the following relation $Dt/st = D_c(T_z)/sc(T_z)$ is substantially satisfied.

[0153] This allows compensating, at the preselected wavelength λ , both values of chromatic dispersion $Dt \cdot Lt$ comprised in a predetermined interval of values, as temperature varies between T_x and T_y , and the chromatic dispersion slope st at a temperature T_z .

EXAMPLE 4.1

[0154] The Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of TW+ optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km. An optical transmission fibre of the TW+ type has a value of the chromatic dispersion coefficient D_t equal to about 4.0 ps/(nm*Km), a value of the chromatic dispersion slope st equal to about 0.0715 ps/(nm²*Km), and a value of the D_t/st ratio equal to about 55.9 nm⁻¹ (for chromatic dispersion values $Dt \cdot Lt$ of a TW+ optical fibre as length L_t varies, reference shall be made to the values shown in Table 2, first line).

[0155] The values of $D_c(T)$, $sc(T)$ and $D_c(T)/sc(T)$ as temperature T of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.140 mm varies, are shown in Table 11.

Table 11

T (°C)	-20	20	40	60
Dc(T) ps/(nm*kM)	-47.68	-43.13	-40.86	-38.59
sc(T) ps/(nm ² *km)	-0.805	-0.796	-0.79	-0.785
Dc(T)/sc(T) (nm ⁻¹)	59.19	54.18	51.72	49.17

[0156] The values of Table 11 show that, with two units 100 having two respective holey optical fibres 12 with the above features and length L_c respectively of about 7.23 Km and 9.05 Km, it is possible to compensate chromatic dispersion $Dt \cdot Lt$ of TW+ optical fibre portions having lengths comprised between about 73.9 and 86.3 km and, respectively, 92.4 and 107.8 km, as temperature varies from -20 to 40°C.

[0157] Moreover, at temperature T_z of about 10°C, unit 100 having the holey optical fibre 12 with length L_c of about 7.23 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW+ optical fibre portion of 80 Km, (that is, at temperature T_z of 10°C the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/st).

[0158] In turn, at temperature T_z of about 10°C, unit 100 having the holey optical fibre 12 with length L_c of about 9.05 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW+ optical fibre portion of 100 Km.

[0159] At other temperatures T comprised between -20 and 40°C different from 10°C (that is, for the other TW+ optical transmission fibre portions having lengths L_t different from 80 or 100 Km), the chromatic dispersion slope st is not totally compensated. More in particular, at such temperatures there is a residual chromatic dispersion slope (after the passage of an optical signal through a TW+ optical transmission fibre portion and a unit 100 of the invention)

EP 1 273 937 A1

comprised between -0.0054 and +0.0037 and between -0.0054 and +0.0036 in the case of holey optical fibre 12 with length L_c of 7.23 Km and, respectively, 9.05 Km.

[0160] The above results are summarised in Table 12.

Table 12

Lc (Km)	Lt (Km) - TW+	Tx-Ty	residual_s ps/(nm ² *km)
7.23	[73.9 - 86.3]	[-20/40°C]	[-0.0054/+ 0.0037]
9.05	[92.4 - 107.8]	[-20/40°C]	[-0.0054/+ 0.0036]

[0161] Considering, for example, that in the Erbium band (1530-1570 nm), a 40 Gb/s system typically tolerates, in terms of bit error rate, substantially the following absolute values of the residual chromatic dispersion slope (residual_s):

residual_s <0.00125 ps/(nm²*km) for links of 10000 Km
 residual_s <0.001563 ps/(nm²*km) for links of 8000 Km
 residual_s <0.001953 ps/(nm²*km) for links of 7000 Km
 residual_s <0.002343 ps/(nm²*km) for links of 6000 Km
 residual_s <0.002734 ps/(nm²*km) for links of 5000 Km
 residual_s <0.003125 ps/(nm²*km) for links of 4000 Km
 residual_s <0.00468 ps/(nm²*km) for links of 3000 Km
 residual_s <0.00625 ps/(nm²*km) for links of 2000 Km

the above units 100 can be used in a 40 Gb/s WDM optical transmission system for compensating chromatic dispersion and chromatic dispersion slope of TW+ optical transmission fibre portions in links having lengths up to about 2500 Km.

EXAMPLE 4.2

[0162] Moreover, the Applicant has determined the values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x-T_y and $residual_s$ in the case of a TW+ optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.505 mm. The values thus found are shown in Tables 13 and 14.

Table 13

T (°C)	-20	20	80
$D_c(T)$ ps/(nm*km)	-14.8	-13.3	-10.99
$sc(T)$ ps/(nm ² *km)	-0.22	-0.217	-0.214
$D_c(T)/sc(T)$ (nm ⁻¹)	67.7	61.1	51.3

Table 14

Lc (Km)	Lt (Km) - TW+	Tx-Ty	residual_s ps/(nm ² *km)
26.4	[72.5 - 87.8]	[+20/80°C]	[-0.0047/+ 0.0048]
33	[90.6 - 109.7]	[+20/80°C]	[-0.0047/+ 0.0047]

[0163] Moreover, in this case, the unit 100 having the holey optical fibre 12 with length L_c of about 26.4 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW+ optical fibre portion of 80 Km, at the temperature T_z of about 50°C (that is, at the temperature T_z of 50°C, the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/st).

[0164] In turn, the unit 100 having the holey optical fibre 12 with length L_c of about 33 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW+ optical fibre portion of 100 Km at the temperature T_z of about 50°C.

[0165] Comparing the values of table 12 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.140 μ m - with those of Table 14 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.505 μ m - it can be noted that, decreasing ratio d/Λ :

- the unit is less efficient (greater length L_c of the holey optical fibres 12);
- the amplitude of the interval of lengths L_t that can be compensated is slightly greater;
- the amplitude of the interval T_x-T_y has remained unchanged; and
- the maximum absolute value of the residual_s is slightly lower.

[0166] Moreover, the Applicant has found that a lower d/Λ ratio corresponds to a greater effective area of the holey optical fibre 12.

EXAMPLE 5.1

[0167] Moreover, the Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of TW optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km. An optical transmission fibre of the TW type has a value of the chromatic dispersion coefficient D_t equal to about 2.4 ps/(nm²*Km), a value of the chromatic dispersion slope st equal to about 0.0716 ps/(nm²*Km), and a value of the D_t/st ratio equal to about 33.5 nm⁻¹ (for chromatic dispersion values $D_t \cdot L_t$ in the case of a TW optical fibre as length L_t varies, reference shall be made to the values shown in Table 2, last line).

[0168] The values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x-T_y and residual_s in the case of a TW optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.156 mm are shown in Tables 15 and 16.

Table 15

T (°C)	Dc (ps/nm/km)	sc ps/(nm ² *km)	Dc/sc (nm ⁻¹)
-20	-29.774	-0.759	39.22
0	-27.635	-0.754	36.65
20	-25.497	-0.749	33.96
40	-23.358	-0.744	31.39
60	-21.219	-0.739	28.71

Table 16

Lc (Km)	Lt (Km) - TW	Tx-Ty	residual _s ps/(nm ² *km)
7.53	[73.3-86.7]	[0/40 °C]	[-0.00447 / + 0.00553]
9.41	[91.5-108.4]	[0/40 °C]	[-0.00454 / + 0.00556]

[0169] The values of Table 16 show that, with two units 100 having two respective holey optical fibres 12 with the above features and length L_c respectively of about 7.53 Km and 9.41 Km, it is possible to compensate the chromatic dispersion $D_t \cdot L_t$ of TW optical fibre portions having lengths comprised between about 73.3 and 86.7 and, respectively, 91.5 and 108.4, as temperature varies from 0 a to 40°C.

[0170] Moreover, at temperature T_z of about 20°C, unit 100 having the holey optical fibre 12 with length L_c of about 7.53 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW optical fibre portion of 80 Km, (that is, at temperature T_z of 20°C the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/st).

[0171] In turn, at temperature T_z of about 20°C, unit 100 having the holey optical fibre 12 with length L_c of about 9.41 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW optical fibre portion of 100 Km.

[0172] The absolute value of the residual chromatic dispersion slope (residual_s) at the other temperatures comprised between 0 and 40°C is less than or equal to, about 0.0055 ps/(nm²*Km). That is, the above units 100 can be used in a 40 Gb/s WDM optical transmission system for compensating chromatic dispersion and chromatic dispersion slope of TW optical transmission fibre portions in links having lengths up to about 2500 Km.

EXAMPLE 5.2

[0173] Moreover, the Applicant has determined the values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x-T_y and $residual_s$ in the case of a TW optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.525 mm. The values thus found are shown in Tables 17 and 18.

Table 17

T (°C)	10	20	30	50
Dc(T) ps/(nm*km)	-7.786	-7.415	-6.96	-6.33
sc(T) ps/(nm ² *km)	-0.209	-0.208	-0.2075	-0.207
Dc(T)/sc(T) (nm ⁻¹)	37.34	35.5	33.5	30.51

Table 18

Lc (Km)	Lt (Km) - TW	Tx-Ty	residual_s ps/(nm ² *km)
27.25	[71.5 - 88.5]	[+10/50°C]	[-0.00535/+ 0.00546]
34.06	[89 - 110.6]	[+10/50°C]	[-0.00558/+ 0.00545]

[0174] In this case, the unit 100 having the holey optical fibre 12 with length L_c of about 27.25 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW optical fibre portion of 80 Km, at the temperature T_z of 30°C (that is, at the temperature T_z of 30°C, the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/st).

[0175] In turn, the unit 100 having the holey optical fibre 12 with length L_c of about 34.06 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a TW optical fibre portion of 100 Km at the temperature T_z of 30°C.

[0176] Comparing the values of table 16 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.156 mm - with those of Table 18 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.525 mm - it can be noted that, decreasing ratio d/Λ :

- the unit is less efficient (greater length L_c of the holey optical fibres 12);
- the amplitude of the interval of lengths L_t that can be compensated is slightly greater;
- the amplitude of the interval T_x-T_y has remained unchanged; and
- the maximum absolute value of the $residual_s$ is slightly higher.

Moreover, the Applicant has found that a lower d/Λ ratio corresponds to a greater effective area of the holey optical fibre 12.

EXAMPLE 6.1

[0177] Moreover, the Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of TW RS optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km. An optical transmission fibre of the TW RS type has a value of the chromatic dispersion coefficient D_t equal to about 5.7 ps/(nm*Km), a value of the chromatic dispersion slope st equal to about 0.045 ps/(nm²*Km), and a value of the D_t/st ratio equal to about 126.7 nm⁻¹ (for chromatic dispersion values D_t*L_t in the case of a TW RS optical fibre as length L_t varies, reference shall be made to the values shown in Table 8).

[0178] The values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x-T_y and $residual_s$ in the case of a TW RS optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.080 mm are shown in Tables 19 and 20.

EP 1 273 937 A1

Table 19

T (°C)	Dc (ps/nm/km)	sc ps/(nm ² *km)	Dc/sc (nm ⁻¹)
-20	-131.46	-1.002	131.13
20	-125.76	-0.9911	126.88
60	-120.06	-0.9803	122.4

Table 20

Lc (Km)	Lt(Km)-TW RS	Tx-Ty	residual_s ps/(nm ² *km)
3.62	[76.2-86.5]	[-20/60 °C]	[-0.0015 / + 0.0029]
4.53	[95.4-104.5]	[-20/60 °C]	[-0.0015 / + 0.0015]

[0179] The values of Table 20 show that, with two units 100 having two respective holey optical fibres 12 with the above features and length Lc respectively of about 3.62 Km and 4.53 Km, it is possible to compensate the chromatic dispersion Dt*Lt of TW RS optical fibre portions having lengths comprised between about 76.2 and 86.5 and, respectively, 95.4 and 104.5, as temperature varies from -20 to 60°C.

[0180] Moreover, at temperature Tz of about 20°C, unit 100 having the holey optical fibre 12 with length Lc of about 3.62 Km is capable of compensating, besides the chromatic dispersion coefficient Dt, also the chromatic dispersion slope st of a TW RS optical fibre portion of 80 Km, (that is, at temperature Tz of 20°C the ratio Dc(Tz)/sc(Tz) is almost equal to ratio Dt/st).

[0181] In turn, at temperature Tz of about 20°C, unit 100 having the holey optical fibre 12 with length Lc of about 4.53 Km is capable of compensating, besides the chromatic dispersion coefficient Dt, also the chromatic dispersion slope st of a TW RS optical fibre portion of 100 Km.

[0182] The absolute value of the residual chromatic dispersion slope (residual_s) at the other temperatures comprised between -20 and 60°C is less than or equal to, about 0.0029 ps/(nm²*Km). That is, the above units 100 can be used in a 40 Gb/s WDM optical transmission system for compensating chromatic dispersion and chromatic dispersion slope of TW RS optical transmission fibre portions in links having length up to about 4500 Km.

EXAMPLE 6.2

[0183] Moreover, the Applicant has determined the values of Dc(T), sc(T), Dc(T)/sc(T), Lc, Lt, Tx-Ty and residual_s in the case of a TW RS optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.450 mm. The values thus found are shown in Tables 21 and 22.

Table 21

T (°C)	-20	20	60
Dc(T) ps/(nm*km)	-31.798	-30.113	-28.428
sc(T) ps/(nm ² *km)	-0.2400	-0.2385	-0.2371
Dc(T)/sc(T) (nm ⁻¹)	132.46	126.22	119.8

Table 22

Lc (Km)	Lt(Km) - TW RS	Tx-Ty	residual_s ps/(nm ² *km)
15.14	[75.5-84.4]	[-20/60°C]	[-0.0021 / + 0.00168]
18.93	[94.4-105.6]	[-20/60°C]	[-0.0021 / + 0.00167]

[0184] Moreover, in this case, the unit 100 having the holey optical fibre 12 with length Lc of about 15.14 Km is capable of compensating, besides the chromatic dispersion coefficient Dt, also the chromatic dispersion slope st of a TW RS optical fibre portion of 80 Km, at the temperature Tz of 20°C (that is, at the temperature Tz of about 20°C, the ratio Dc(Tz)/sc(Tz) is almost equal to ratio Dt/st).

[0185] In turn, the unit 100 having the holey optical fibre 12 with length Lc of about 18.93 Km is capable of compen-

sating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope s_t of a TW RS optical fibre portion of 100 Km at the temperature T_z of about 20°C.

[0186] Comparing the values of table 20 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.080 mm - with those of Table 22 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.450 mm - it can be noted that, decreasing ratio d/Λ :

- the unit is less efficient (greater length L_c of the holey optical fibres 12);
- the amplitude of the interval of lengths L_t that can be compensated is slightly greater;
- the amplitude of the interval T_x - T_y has remained unchanged; and
- the maximum absolute value of the residual_s is lower.

[0187] Moreover, the Applicant has found that a lower d/Λ ratio corresponds to a greater effective area of the holey optical fibre 12.

EXAMPLE 7.1

[0188] Moreover, the Applicant has considered the case of compensating, in a reconfigurable manner, the chromatic dispersion of SMF optical transmission fibre portions having lengths L_t comprised between about 70 and 110 Km. An optical transmission fibre of the SMF type has a value of the chromatic dispersion coefficient D_t equal to about 17 ps/(nm*Km), a value of the chromatic dispersion slope s_t equal to about 0.068 ps/(nm²*Km), and a value of the D_t/s_t ratio equal to about 251 nm⁻¹ (for chromatic dispersion values $D_t \cdot L_t$ in the case of a SMF optical fibre as length L_t varies, reference shall be made to the values shown in Table 5).

[0189] The values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x - T_y and residual_s in the case of a SMF optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 0.970 mm are shown in Tables 23 and 24.

Table 23

T (°C)	Dc (ps/nm/km)	sc ps/(nm ² *km)	Dc/sc (nm ⁻¹)
-20	-355.15	-1.3834	256.72
20	-347.11	-1.3749	252.46
60	-339.07	-1.3665	248.13

Table 24

Lc (Km)	Lt (Km) - SMF	Tx-Ty	residual _s ps/(nm ² *km)
3.92	[78.1-81.8]	[-20/60 °C]	[-0.00078 / + 0.00141]
4.89	[97.7-102.3]	[-20/60 °C]	[-0.000775 / + 0.00141]

[0190] The values of Table 24 show that, with two units 100 having two respective holey optical fibres 12 with the above features and length L_c respectively of about 3.92 Km and 4.89 Km, it is possible to compensate the chromatic dispersion $D_t \cdot L_t$ of SMF optical fibre portions having lengths comprised between about 78,1 and 81,8 and, respectively, 97.7 and 102.3, as temperature varies from -20 a to 60°C.

[0191] Moreover, at temperature T_z of about 20°C, unit 100 having the holey optical fibre 12 with length L_c of about 3.92 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope s_t of a SMF optical fibre portion of 80 Km, (that is, at temperature T_z of 20°C the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/s_t).

[0192] In turn, at temperature T_z of about 20°C, unit 100 having the holey optical fibre 12 with length L_c of about 4.89 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope s_t of a SMF optical fibre portion of 100 Km.

[0193] The absolute value of the residual chromatic dispersion slope (residual_s) at the other temperatures comprised between -20 and 60°C is less than or equal to, about 0.0014 ps/(nm²*Km). That is, the above units 100 can be used in a 40 Gb/s WDM optical transmission system for compensating chromatic dispersion and chromatic dispersion

slope of SMF optical transmission fibre portions in links having length up to about 8000 Km.

EXAMPLE 7.2

5 [0194] Moreover, the Applicant has determined the values of $D_c(T)$, $sc(T)$, $D_c(T)/sc(T)$, L_c , L_t , T_x-T_y and $residual_s$ in the case of a SMF optical transmission fibre and of a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.359 mm. The values thus found are shown in Tables 25 and 26.

Table 25

T (°C)	-20	20	60
$D_c(T)$ ps/(nm*km)	-67.242	-65.362	-63.483
$sc(T)$ ps/(nm ² *km)	-0.26075	-0.26075	-0.26075
$D_c(T)/sc(T)$ (nm ⁻¹)	257.89	250.68	243.47

Table 26

L_c (Km)	L_t (Km) - SMF	T_x-T_y	$residual_s$ ps/(nm ² *km)
20.8	[77.7 - 82.3]	[-20/60°C]	[-0.0014 / + 0.0017]
26	[97 - 102.8]	[-20/60°C]	[-0.0015 / + 0.0016]

25 [0195] Moreover, in this case, the unit 100 having the holey optical fibre 12 with length L_c of about 20.8 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a SMF optical fibre portion of 80 Km, at the temperature T_z of about 20°C (that is, at the temperature T_z of 20°C, the ratio $D_c(T_z)/sc(T_z)$ is almost equal to ratio D_t/st).

30 [0196] In turn, the unit 100 having the holey optical fibre 12 with length L_c of about 26 Km is capable of compensating, besides the chromatic dispersion coefficient D_t , also the chromatic dispersion slope st of a SMF optical fibre portion of 100 Km at the temperature T_z of about 20°C.

[0197] Comparing the values of table 24 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 0.970 mm - with those of table 26 - obtained with a holey optical fibre 12 having a ratio d/Λ equal to about 0.5 and a pitch Λ equal to about 1.359 mm - it can be noted that, decreasing ratio d/Λ :

- 35 • the unit is less efficient (greater length L_c of the holey optical fibres 12);
- the amplitude of the interval of lengths L_t that can be compensated is slightly greater;
- the amplitude of the interval T_x-T_y has remained unchanged; and
- 40 • the maximum absolute value of the $residual_s$ is greater.

Moreover, the Applicant has found that a lower d/Λ ratio corresponds to a greater effective area of the holey optical fibre 12.

45 Figure 4 shows an alternative embodiment of unit 100. This embodiment is totally similar to that of figure 3a except in that it also comprises a second holey optical fibre 12' and that the temperature adjusting device 16 is also suitable for bringing and maintaining the second holey optical fibre 12' at a temperature T' selectable in a predetermined interval $T_x'-T_y'$.

Similarly to the first holey optical fibre 12, also the second holey optical fibre 12' has a length L_c' , a core region 13' and a cladding region 14' surrounding the core region 13' (figure 1).

50 In the embodiment shown in figure 1, the cladding region 14' comprises two rings of holes surrounding the core region 13' and passing through the holey optical fibre portion 12' longitudinally for its entire length.

The two rings of holes have hexagonal shape. Moreover, the holes of the two rings have a substantially equal diameter d' , and are spaced from one another according to a pitch Λ' .

55 For compensating at the preselected wavelength λ both the chromatic dispersion coefficient D_t and the chromatic dispersion slope st for different chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval, the hole diameter and pitch of the first and second holey fibre 12, 12', the lengths L_c and L_c' , and the intervals of temperature T_x-T_y and $T_x'-T_y'$ are advantageously selected so that at the preselected wavelength λ ,

EP 1 273 937 A1

- the first and the second holey optical fibre 12, 12' have such value of chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and such value of chromatic dispersion coefficient $Dc(T)$ and, respectively, $Dc(T')$ that, as temperatures T, T' vary in a predetermined manner between value T_x and value T_y and, respectively, between value T_x' and value T_y' , the following relation (J) is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{Dc(T)}{sc(T)} \cdot Lc + \frac{Dc(T')}{sc(T')} \cdot Lc'}{Lc + Lc'} ;$$

and

- the first and the second holey optical fibre 12, 12' have such value of chromatic dispersion coefficients $Dc(T)$ and, respectively, $Dc(T')$ in function of temperature that, as temperatures T, T' vary in said predetermined manner between value T_x and value T_y and, respectively, between value T_x' and value T_y' , the following relation (K) is substantially satisfied

$$Dt \cdot Lt = - [Dc(T) \cdot Lc + Dc(T') \cdot Lc']$$

for all values of chromatic dispersion $Dt \cdot Lt$ comprised in said predetermined interval of values.

[0198] As temperatures T and T' vary in predetermined manner in the intervals of temperatures T_x-T_y and $T_x'-T_y'$, this last embodiment of the invention advantageously allows compensating, with a single unit 100, not only chromatic dispersion $Dt \cdot Lt$ of optical fibre portions having different lengths Lt and same chromatic dispersion coefficient Dt , but also the chromatic dispersion slope st .

[0199] In other words, this last embodiment allows compensating both the chromatic dispersion slope and the chromatic dispersion coefficient of optical transmission fibre portions of the same type (that is, having the same values of chromatic dispersion slope st and of chromatic dispersion coefficient Dt) but having different lengths Lt (that is, having different chromatic dispersion values $Dt \cdot Lt$).

EXAMPLE 8

[0200] The Applicant has considered the case of compensating TW+ optical transmission fibre portions having lengths Lt comprised between about 90 and 110 km and a chromatic dispersion coefficient Dt equal to about 4 ps/(mn·Km), a chromatic dispersion slope st equal to about 0.0715 and a ratio Dt/st equal to about 55.9 (for chromatic dispersion values $Dt \cdot Lt$ in the case of a TW+ optical fibre, as length Lt varies, reference shall be made to the values shown in Table 2, first line).

[0201] Tables 27, 28 and 29 respectively show

- the values of $Dc(T)$ $sc(T)$ and $Dc(T)/sc(T)$ as temperature T of the first holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.140 mm varies;
- the values of $Dc(T')$ $sc(T')$ and $Dc(T')/sc(T')$ as temperature T' of the second holey optical fibre 12' having a ratio d/Λ' equal to about 0.5 and a pitch Λ' equal to about 1.505 mm varies;
- the values of $Dc(T')$ $sc(T')$ and $Dc(T')/sc(T')$ as temperature T' of the second holey optical fibre 12' having a ratio d/Λ' equal to about 0.5 and a pitch Λ' equal to about 1.510 mm varies.

Table 27

T (°C)	Dc ps/(nm·km)	sc ps/(nm ² ·km)	Dc/sc(nm ⁻¹)
-20	-47.68	-0.805	59.19
20	-43.13	-0.796	54.18
60	-38.59	-0.785	49.17

Table 28

T' (°C)	Dc' ps/(nm*km)	sc' ps/(nm ² *km)	Dc'/sc' (nm ⁻¹)
-20	-14.8	-0.219	67.7
20	-13.3	-0.217	61.14
60	-11.75	-0.215	54.58

Table 29

T' (°C)	Dc' ps/(nm*km)	sc' ps/(nm ² *km)	Dc'/sc' (nm ⁻¹)
-20	-13.3	-0.218	61.1
20	-11.7	-0.213	54.83
60	-10.12	-0.229	44.05

[0202] With reference to the two optical fibres of tables 28 and 29, having the same ratio d/Λ' but different pitch Λ' by 5 nm, the Applicant notes that, as shown by the values of the same tables 28 and 29 and by the following tables 30-33, even though parameters Dc' and sc' are very sensitive to slight dimensional variations with respect to the considered dimensional scale, in the presence of such dimensional variations it is anyway possible to obtain the desired compensation of the chromatic dispersion and of the chromatic dispersion slope, by suitably selecting the pairs of temperature T and T' and the intervals Tx-Ty and Tx'-Ty'.

[0203] Table 30 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, Dc_j/sc_j (given by relation J) and residual_s in the case of intervals of temperatures Tx-Ty, Tx'-Ty' of 100 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 27 and the second holey optical fibre 12' with the features shown in table 28.

Table 30

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW+ (km)	Dc _j /sc _j (nm ⁻¹)	residual _s ps/nm ² *km
-20	-20	7.78	5.6	13.39	113.7	63	0.010
+80	-20	7.78	5.6	13.39	108.2	55.9	0
-20	+80	7.78	5.6	13.39	91.7	55.9	0
+80	+80	7.78	5.6	13.39	86.2	48.6	-0.0046

[0204] The values of Table 30 show that, with a unit 100 having two holey optical fibres 12, 12' with the above features and lengths Lc and Lc' respectively of about 7.78 Km and 5.6 Km, it is possible to compensate the chromatic dispersion Dt*Lt of TW+ optical fibre portions having lengths comprised between about 86.2 and 113.7 as the pairs of temperature T, T' vary within the intervals of temperature Tx-Ty and Tx'-Ty' comprised between -20 and 80°C.

[0205] Moreover, by suitably selecting the pairs of temperature T, T' in said intervals of temperature Tx-Ty and Tx'-Ty', it is possible to compensate, besides chromatic dispersion Dt*Lt, also the chromatic dispersion slope st (null residual_s) of TW+ optical fibre portions having lengths comprised between about 91.7 and 108.2 Km.

[0206] Similarly, table 31 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, and residual_s in the case of intervals of temperatures Tx-Ty of 80 degrees and Tx-Ty' of 55 degrees, and of a unit 100 having the first holey optical fibre 12 with the features shown in table 27 and the second holey optical fibre 12' with the features shown in table 28.

Table 31

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW+ (km)	residual _s ps/nm ² *km
-20	15	6.99	7.77	14.76	110	0.00658
60	15	6.99	7.77	14.76	106	0
-20	70	6.99	7.77	14.76	94	0
60	70	6.99	7.77	14.76	90	-0.0038

[0207] Similarly, table 32 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, and residual_s in the case of intervals of temperatures Tx-Ty, Tx'-Ty' of 60 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 27 and the second holey optical fibre 12' with the features shown in table 29.

Table 32

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW+ (km)	residual_s ps/nm ² *km
-20	-20	7.57	5.33	12.9	107.8	0.0037
40	-20	7.57	5.33	12.9	104.7	0
-20	40	7.57	5.33	12.9	95.2	0
40	40	7.57	5.33	12.9	92.2	-0.005

[0208] Comparing the values of table 32 with those of tables 12 and 14 relating to the similar case of compensation of TW+ optical transmission fibre with a unit 100 having a single holey optical fibre 12 and an interval of temperatures Tx-Ty of 60 degrees, it can be noted that, with respect to unit 100 with a single holey optical fibre 12, unit 100 with two holey optical fibres 12, 12' exhibits:

- almost the same interval of lengths Lt of the TW+ optical transmission fibre portions that can be compensated, and
- smaller lengths Lc, Lc' of the single holey optical fibres 12, 12' (this allows simplifying the single fibre production process).

[0209] Moreover, figure 9 shows the values of the residual chromatic dispersion slope (residual_s) at the various lengths Lt of the TW+ optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 32 (curve A) and in the case of a unit 100 according to the values of table 12 (curve B).

[0210] From such figure it can be noted that, in general, in the case of a unit 100 with two holey optical fibre portions 12, 12' the residual_s is much lower, in absolute value, with respect to the case of a unit 100 with a single holey optical fibre portion 12.

[0211] Finally, table 33 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, and residual_s in the case of intervals of temperatures Tx-Ty, Tx'-Ty' of 40 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 27 and the second holey optical fibre 12' with the features shown in table 29.

Table 33

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW+ (km)	residual_s ps/nm ² *km
0	-20	7.6	5.7	13.3	105.37	0.00172
40	-20	7.6	5.7	13.3	103.1	0
0	20	7.6	5.7	13.3	96.9	0
40	20	7.6	5.7	13.3	94.6	-0.0043

[0212] In brief, a unit 100 having two holey optical fibres 12, 12' independently adjustable in temperature is preferable with respect to a unit 100 with a single holey optical fibre 12 both in terms of length of the single holey optical fibres 12, 12' and in terms of residual_s.

EXAMPLE 9

[0213] Moreover, the Applicant has considered the case of compensating TW optical transmission fibre portions having lengths Lt comprised between about 90 and 110 km and a chromatic dispersion coefficient Dt equal to about 2.4 ps/(nm*Km), a chromatic dispersion slope st equal to about 0.0716 and a ratio Dt/st equal to about 33.5 (for chromatic dispersion values Dt*Lt in the case of a TW optical fibre, as length Lt varies, reference shall be made to the values shown in Table 2, last line).

[0214] Tables 34 and 35 respectively show

- the values of Dc(T) sc(T) and Dc(T)/sc(T) as temperature T of the first holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.156 mm varies; and

EP 1 273 937 A1

- the values of $D_c(T')$, $sc(T')$ and $D_c(T')/sc(T')$ as temperature T' of the second holey optical fibre 12' having a ratio d/Λ' equal to about 0.5 and a pitch Λ' equal to about 1.525 mm varies.

Table 34

T (°C)	Dc ps/(nm*km)	sc ps/(nm ² *km)	Dc/sc(nm-1)
-20	-29.774	-0.759	39.22
20	-25.49	-0.749	33.96
60	-21.219	-0.739	28.71

Table 35

T' (°C)	Dc' ps/(nm*km)	sc' ps/(nm ² *km)	Dc'/sc' (nm-1)
-20	-8.9	-0.2106	42.28
20	-7.415	-0.2085	35.5
60	-5.93	-0.2064	28.73

[0215] Table 36 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, D_c/sc_j (given by the above relation J) and residual_s in the case of intervals of temperatures Tx-Ty of 80 degrees and Tx'-Ty' of 50 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 34 and the second holey optical fibre 12' with the features shown in table 35.

Table 36

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW (km)	D_c/sc_j (nm ⁻¹)	residual_s ps/nm ² *km
-20	10	7.17	8.38	15.55	115.8	38.4	0.0077
60	10	7.17	8.38	15.55	109.5	33.5	0
-20	60	7.17	8.38	15.55	90.5	33.5	0
60	60	7.17	8.38	15.55	84	28.7	-0.009

[0216] The values of Table 36 show that, with a unit 100 having two holey optical fibres 12, 12' with the above features and lengths Lc and Lc' respectively of about 7.17 Km and 8.38 Km, it is possible to compensate the chromatic dispersion $D_t \cdot Lt$ of TW optical fibre portions having lengths comprised between about 84 and 115,8 as the pairs of temperature T, T' vary within the intervals of temperature Tx-Ty and Tx'-Ty' comprised between -20 and 60°C and, respectively, 10 and 60°C.

[0217] Moreover, by suitably selecting the pairs of temperature T, T' in said intervals of temperature Tx-Ty and Tx'-Ty', it is possible to compensate, besides chromatic dispersion $D_t \cdot Lt$, also the chromatic dispersion slope st (null residual_s) of TW optical fibre portions having lengths comprised between about 90.5 and 109.5 Km.

[0218] Similarly, table 37 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, D_c/sc_j (given by relation J) and residual_s in the case of intervals of temperatures Tx-Ty of 60 degrees and Tx'-Ty' of 35 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 34 and the second holey optical fibre 12' with the features shown in table 35.

Table 37

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW (km)	D_c/sc_j (nm ⁻¹)	residual_s ps/nm ² *km
-10	15	6.27	11.42	17.69	114.28	37.31	0.0069
50	15	6.27	11.42	17.69	108.13	33.5	0
-10	50	6.27	11.42	17.69	91.86	33.5	0
50	50	6.27	11.42	17.69	85.7	29.81	-0.0073

[0219] Finally, table 38 shows the values of T , T' , L_c , L_c' , L_c+L_c' , L_t , D_c/sc_j (given by relation J) and $residual_s$ in the case of intervals of temperatures T_x-T_y of 40 degrees and $T_x'-T_y'$ of 30 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 34 and the second holey optical fibre 12' with the features shown in table 35.

Table 38

T (°C)	T' (°C)	L_c (km)	L_c' (km)	L_c+L_c' (km)	L_t TW (km)	D_c/sc_j (nm ⁻¹)	$residual_s$ ps/ nm ² *km
0	20	7.44	7.32	14.76	108.29	36.21	0.005
0	20	7.44	7.32	14.76	104.93	33.5	0
40	50	7.44	7.32	14.76	95	33.5	0
40	50	7.44	7.32	14.76	91.67	30.91	-0.0047

[0220] Comparing the values of table 38 with those of tables 16 and 18 relating to the similar case of compensation of TW optical transmission fibre with a unit 100 having a single holey optical fibre 12 and an interval of temperatures T_x-T_y of 40 degrees, it can be noted that, with respect to unit 100 with a single holey optical fibre 12, unit 100 with two holey optical fibres 12, 12' exhibits:

- almost the same interval of lengths L_t of the TW+ optical transmission fibre portions that can be compensated, and
- smaller lengths L_c , L_c' of the single holey optical fibres 12, 12' (this allows simplifying the single fibre production process).

[0221] Moreover, figure 10 shows the values of the residual chromatic dispersion slope ($residual_s$) at the various lengths L_t of the TW optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 38 (curve A) and in the case of a unit 100 according to the values of table 16 (curve B).

[0222] From such figure it can be noted that, in general, in the case of a unit 100 with two holey optical fibre portions 12, 12' the $residual_s$ is much lower, in absolute value, with respect to the case of a unit 100 with a single holey optical fibre portion 12.

EXAMPLE 10

[0223] Moreover, the Applicant has considered the case of compensating TW RS optical transmission fibre portions having lengths L_t comprised between about 90 and 110 km and a chromatic dispersion coefficient D_t equal to about 5.7 ps/(nm*Km), a chromatic dispersion slope st equal to about 0.045 and a ratio D_t/st equal to about 126.7 (for chromatic dispersion values D_t*L_t in the case of a TW RS optical fibre, as length L_t varies, reference shall be made to the values shown in Table 8).

[0224] Tables 39 and 40 respectively show

- the values of $D_c(T)$, $sc(T)$ and $D_c(T)/sc(T)$ as temperature T of the first holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 1.079 mm varies; and
- the values of $D_c(T')$, $sc(T')$ and $D_c(T')/sc(T')$ as temperature T' of the second holey optical fibre 12' having a ratio d/Λ' equal to about 0.5 and a pitch Λ' equal to about 1.450 mm varies.

Table 39

T (°C)	D_c ps/(nm*Km)	sc ps/(nm ² *km)	D_c/sc (nm ⁻¹)
-20	-131.46	-1.002	131.13
20	-125.76	-0.9911	126.88
60	-120.06	-0.9803	122.4

Table 40

T' (°C)	Dc' ps/(nm*km)	sc' ps/(nm ² *km)	Dc'/sc' (nm ⁻¹)
-20	-31.79	-0.24	132.46
20	-30.113	-0.2385	126.22
60	-28.428	-0.237	119.8

[0225] Table 41 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, Dc/sc_j (given by the above relation J) and residual_s in the case of intervals of temperatures Tx-Ty, Tx'-Ty' of 80 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 39 and the second holey optical fibre 12' with the features shown in table 40.

Table 41

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW RS (km)	Dc _j /sc _j (nm ⁻¹)	residual _s ps/(nm ² *km)
-20	-20	3.92	2.55	6.47	104.7	131.95	0.00145
60	-20	3.92	2.55	6.47	103.2	126.7	0
-20	60	3.92	2.55	6.47	96.8	126.7	0
60	60	3.92	2.55	6.47	95.3	121.37	-0.0015

[0226] The values of Table 41 show that, with a unit 100 having two holey optical fibres 12, 12' with the above features and lengths Lc and Lc' respectively of about 3.92 Km and 2.55 Km, it is possible to compensate the chromatic dispersion Dt*Lt of TW RS optical fibre portions having lengths comprised between about 95.3 and 104.7 as the pairs of temperature T, T' vary within the intervals of temperature Tx-Ty and Tx'-Ty' comprised between -20 and 60°C.

[0227] Moreover, by suitably selecting the pairs of temperature T, T' in said intervals of temperature Tx-Ty and Tx'-Ty', it is possible to compensate, besides chromatic dispersion Dt*Lt, also the chromatic dispersion slope st (null residual_s) of TW RS optical fibre portions having lengths comprised between about 96.8 and 103.2 Km.

[0228] Comparing the values of table 41 with those of tables 20 and 22 relating to the similar case of compensation of TW RS optical transmission fibre with a unit 100 having a single holey optical fibre 12 and an interval of temperatures Tx-Ty of 80 degrees, it can be noted that, with respect to unit 100 with a single holey optical fibre 12, unit 100 with two holey optical fibres 12, 12' exhibits:

- almost the same interval of lengths Lt of the TW RS optical transmission fibre portions that can be compensated, and
- smaller lengths Lc, Lc' of the single holey optical fibres 12, 12' (this allows simplifying the single fibre production process).

[0229] Moreover, figure 11 shows the values of the residual chromatic dispersion slope (residual_s) at the various lengths Lt of the TW RS optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 41 (curve A) and in the case of a unit 100 according to the values of table 20 (curve B).

[0230] From such figure it can be noted that, in general, in the case of a unit 100 with two holey optical fibre portions 12, 12' the residual_s is much lower, in absolute value, with respect to the case of a unit 100 with a single holey optical fibre portion 12.

[0231] Finally, table 42 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, Dc/sc_j (given by relation J) and residual_s in the case of intervals of temperatures Tx-Ty, Tx'-Ty' of 60 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 39 and the second holey optical fibre 12' with the features shown in table 40.

Table 42

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW RS (km)	Dc _j /sc _j (nm ⁻¹)	residual _s ps/nm ² *km
-10	-10	3.9	2.55	6.46	103.2	130.64	0.00114
50	-10	3.9	2.55	6.46	102.2	126.7	0

Table 42 (continued)

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt TW RS (km)	Dc _j /sc _j (nm ⁻¹)	residual_s ps/nm ² *km
-10	50	3.9	2.55	6.46	97.8	126.7	0
50	50	3.9	2.55	6.46	96.7	122.68	-0.00114

EXAMPLE 11

[0232] The Applicant has considered the case of compensating SMF optical transmission fibre portions having lengths Lt comprised between about 90 and 110 km and a chromatic dispersion coefficient Dt equal to about 17 ps/(mn*Km), a chromatic dispersion slope st equal to about 0.0677 and a ratio Dt/st equal to about 251 (for chromatic dispersion values Dt*Lt in the case of a SMF optical fibre, as length Lt varies, reference shall be made to the values shown in Table 5).

[0233] Tables 43 and 44 respectively show

- the values of Dc(T), sc(T) and Dc(T)/sc(T) as temperature T of the first holey optical fibre 12 having a ratio d/Λ equal to about 0.9 and a pitch Λ equal to about 0.970 mm varies; and
- the values of Dc(T'), sc(T') and Dc(T')/sc(T') as temperature T' of the second holey optical fibre 12' having a ratio d/Λ' equal to about 0.5 and a pitch Λ' equal to about 1.359 mm varies.

Table 43

T (°C)	Dc ps/(nm*Km)	sc ps/(nm ² *km)	Dc/sc(nm-1)
-20	-355.15	-1.3834	256.72
20	-347.11	-1.3749	252.46
60	-339.07	-1.3665	248.13

Table 44

T' (°C)	Dc' ps/(nm*Km)	sc' ps/(nm ² *km)	Dc'/sc' (nm-1)
-20	-67.24	-0.26075	257.89
20	-65.36	-0.26075	250.68
60	-63.48	-0.26075	243.47

[0234] Table 45 shows the values of T, T', Lc, Lc', Lc+Lc', Lt, Dc/sc_j (given by the above relation J) and residual_s in the case of intervals of temperatures Tx-Ty of 80 degrees and Tx'-Ty' of 60 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 43 and the second holey optical fibre 12' with the features shown in table 44.

Table 45

T (°C)	T' (°C)	Lc (km)	Lc' (km)	Lc+Lc' (km)	Lt SMF (km)	Dc _j /sc _j (nm ⁻¹)	residual_s ps/nm ² *km
-20	0	4.25	3.43	7.68	102.3	255.5	0.00133
60	0	4.25	3.43	7.68	101.8	251	0
-20	60	4.25	3.43	7.68	98.3	251	0
60	60	4.25	3.43	7.68	97.7	246	-0.00082

[0235] The values of Table 45 show that, with a unit 100 having two holey optical fibres 12, 12' with the above features and lengths Lc and Lc' respectively of about 4.25 Km and 3.43 Km, it is possible to compensate chromatic dispersion Dt*Lt of SMF optical fibre portions having lengths comprised between about 97.7 and 102.3 as the pairs of temperature

T, T' vary within the intervals of temperature Tx-Ty and Tx'-Ty' comprised between -20 and 60°C and, respectively, 0 and 60°C.

[0236] Moreover, by suitably selecting the pairs of temperature T, T' in said intervals of temperature Tx-Ty and Tx'-Ty', it is possible to compensate, besides chromatic dispersion $D_t \cdot L_t$, also the chromatic dispersion slope s_t (null residual_s) of SMF optical fibre portions having lengths comprised between about 98.3 and 101.8 Km.

[0237] Comparing the values of table 45 with those of tables 24 and 26 relating to the similar case of compensation of SMF optical transmission fibre with a unit 100 having a single holey optical fibre 12 and an interval of temperatures Tx-Ty of 80 degrees, it can be noted that, with respect to unit 100 with a single holey optical fibre 12, unit 100 with two holey optical fibres 12, 12' exhibits:

- almost the same interval of lengths L_t of the SMF optical transmission fibre portions that can be compensated, and
- smaller lengths L_c , $L_{c'}$ of the single holey optical fibres 12, 12' (this allows simplifying the single fibre production process).

[0238] Moreover, figure 12 shows the values of the residual chromatic dispersion slope (residual_s) at the various lengths L_t of the SMF optical transmission fibre portion to be compensated in the case of a unit 100 according to the values of table 45 (curve A) and in the case of a unit 100 according to the values of table 24 (curve B).

[0239] From such figure it can be noted that, in general, in the case of a unit 100 with two holey optical fibre portions 12, 12' the residual s is much lower, in absolute value, with respect to the case of a unit 100 with a single holey optical fibre portion 12.

[0240] Finally, table 46 shows the values of T, T', L_c , $L_{c'}$, $L_c + L_{c'}$, L_t , D_c / s_{c_j} (given by relation J) and residual_s in the case of intervals of temperatures Tx-Ty of 60 degrees and Tx'-Ty' of 45 degrees and of a unit 100 having the first holey optical fibre 12 with the features shown in table 43 and the second holey optical fibre 12' with the features shown in table 44.

Table 46

T (°C)	T' (°C)	L_c (km)	$L_{c'}$ (km)	$L_c + L_{c'}$ (km)	L_t SMF (km)	D_c / s_{c_j} (nm ⁻¹)	residual_s ps/nm ² *km
-20	15	4.24	3.41	7.65	101.7	254.3	0.00126
40	15	4.24	3.41	7.65	101.3	251	0
-20	60	4.24	3.41	7.65	98.7	251	0
40	60	4.24	3.41	7.65	98.3	247.2	-0.00036

[0241] Unit 100 of the invention can be used for compensating the chromatic dispersion, and optionally, the chromatic dispersion slope, of an optical transmission fibre portion of an optical communication line.

[0242] For example, figure 5 shows an optical communication line 1 according to an aspect of the invention, comprising a portion of optical transmission fibre 10 and a unit 100, located downstream of portion 10.

[0243] The optical transmission fibre portion 10 is an optical fibre portion conventionally used for telecommunications.

[0244] More in particular, it is a portion of optical fibre comprising a core and a cladding, both made of a typically silica-based vitreous material, in which the refractive index difference between core and cladding is obtained by incorporating suitable dopants in the vitreous matrix of the core and/or cladding.

[0245] Typical examples of such optical fibres are, as already said above, a conventional SMF optical fibre, a True Wave™ optical fibre, a True Wave Plus™ optical fibre, a True Wave RS™ optical fibre, a LEAF optical fibre, a LEAF Enhanced optical fibre, and a FreeLight™ optical fibre.

[0246] The portion of optical transmission fibre 10 has, at a wavelength λ , a chromatic dispersion coefficient D_t and a chromatic dispersion slope s_t , that are typically positive.

[0247] Moreover, it has a length L_t that can range between some tenths of kilometres and some hundreds of kilometres. Typically, it has a length L_t comprised between 30 and 200 Km.

[0248] Unit 10 has the holey optical fibre 12 specifically designed and the temperature adjusting device 16 specifically adjusted so as to compensate the chromatic dispersion D_t and, optionally, the chromatic dispersion slope s_t of the optical transmission fibre portion 10 having length L_t .

[0249] In an alternative embodiment (not shown), the optical transmission line 1 is totally similar to that of figure 5 except in that it also comprises a conventional compensator device for compensating the chromatic dispersion, located between the optical transmission fibre portion 10 and unit 100.

[0250] In this last embodiment, unit 10 has the holey optical fibre 12 specifically designed and the temperature adjusting device 16 specifically adjusted so as to compensate the residual chromatic dispersion D_t after the passage of an optical signal through the conventional compensator device and, optionally, the chromatic dispersion slope s_t of the optical transmission fibre portion 10 having length L_t .

[0251] The compensator device consists, for example, of a conventional optical circulator associated to a suitable chirped optical fibre Bragg grating or of a conventional optical fibre for compensating the chromatic dispersion.

[0252] The use of a conventional compensator device can, for example, be suitable in the case of optical transmission fibre portions 10 of the SMF or TW RSTM type having relatively high values of chromatic dispersion D_t .

[0253] In fact, in this case, the conventional compensator device can be suitably selected to bring the chromatic dispersion value D_t of such fibre portions to a value comparable to that of TW+TM, Free LightTM, LEAF, LEAF Enhanced and TWTM fibres (see values of table 1) thus allowing the use of two units 100 similar to those of example 1 also for compensating, in a reconfigurable manner, the chromatic dispersion $D_t \cdot L_t$ of SMF and TW RSTM optical transmission fibre portions.

[0254] According to an embodiment shown in figure 6, besides the portion of optical transmission fibre 10 and unit 100, the optical communication line 1 also comprises an optical amplifier 11, located downstream of unit 100.

[0255] As shown in figure 8, the optical amplifier 11 can comprise a portion of optical fibre 15 doped with erbium, and a pump source 18 (for example, a laser source) for pumping the optical fibre 15 at a pumping wavelength λ_p . The pump source 18 is coupled to an input end of the optical fibre 15 through a wavelength selective coupler 17 (for example, of the fused fibre type) so that the signal and pumping light propagate together through the optical fibre 15.

[0256] However, according to the system requirements, the pump source 18 can also be coupled to the output end of the optical fibre 15 (as indicated with reference numeral 19 with a broken line) so that the signal and pumping light propagate in opposed directions through fibre 15.

[0257] Alternatively, each end of fibre 15 can be coupled to a respective pump source.

[0258] In the case of erbium-dope optical fibre 15, wavelength λ_p of the pumping signal typically is equal to about 980 or 1480 nm.

[0259] The described optical amplifier 11 can optionally comprise more than one optical amplification stage.

[0260] Typically, according to an embodiment not shown, the optical communication line 1 of the invention comprises a plurality of optical transmission fibre portions 10, a plurality of optical amplifiers 11 located between one portion of optical transmission fibre 10 and the other one and at least one unit 100 according to the invention, for compensating at least partly the chromatic dispersion and/or the chromatic dispersion slope of the plurality of optical transmission fibre portions 10.

[0261] Such unit 100 can be located at the beginning, at the end or into said optical communication line 1. Advantageously, it is inserted in line 1 between an optical transmission fibre portion 10 and an optical amplifier 11.

[0262] Figure 7 shows an optical communication system 20 according to the invention, comprising a transmitting station 22 for providing a signal at a signal wavelength λ , a receiving station 24 for receiving said signal, and an optical communication line 1 according to the invention, for transmitting the signal from the transmitting station 22 to the receiving station 24.

[0263] According to a preferred embodiment, the optical communication system 20 is a WDM system.

[0264] In this case, the transmitting station 22 is a conventional WDM equipment suitable for providing N optical signals having wavelengths $\lambda_1, \lambda_2, \dots, \lambda_N$ differing from one another, multiplexing them in wavelength and sending them over the optical communication line 1.

[0265] Moreover, the transmitting station 22 also comprises an optical power amplifier (booster, not shown) for amplifying the WDM optical signal before sending it along line 1 (or a certain number of optical power amplifiers in parallel for amplifying optical signals comprised in different wavelength bands).

[0266] Such wavelengths $\lambda_1, \lambda_2, \dots, \lambda_N$ are advantageously selected in an interval of wavelengths comprised between about 1500nm and 1600nm.

[0267] For example, the communication system 10 can be a WDM system with 128 channels spaced from each other by 50 GHz and divided into three bands: 16 channels between 1529 and 1535 nm (first band); 48 channels between 1541 and 1561 nm (second band) and 64 channels between 1575 and 1602 nm (third band).

[0268] Said receiving station 24 comprises a conventional equipment suitable for demultiplexing said N optical signals and sending them to further optional processing stages. Moreover, said receiving station 24 typically comprises also an optical preamplifier (not shown) suitable for bringing the WDM optical signal at a power level suitable for being received by the receiving equipment (or a certain number of optical preamplifiers in parallel for amplifying the optical signals comprised in different wavelength bands).

[0269] Line 1 comprises a plurality of optical amplifiers 11, of the type described with reference to figure 8, for amplifying a signal coming from an upstream portion of line, wherein the signal has attenuated during its propagation along it, and sending it in a downstream portion of line.

[0270] Alternatively, in place of each optical amplifier 11, line 1 can comprise a number of optical amplifiers arranged

in parallel for amplifying the optical signals comprised in different wavelength bands (for example, the first, second and third band mentioned above).

[0271] For example, system 20 can be a submarine optical communication system wherein line 1 comprises a plurality of spans $1_1, 1_2, 1_3, \dots, 1_n$ respectively connecting the transmitting station 22 to the first amplifier 11, such amplifier 11 to the next one, and the last amplifier 11 to the receiving station 24.

[0272] Each span $1_1, 1_2, \dots, 1_n$ comprises, for example, an optical transmission fibre cable 10 and a unit 100 according to the invention (not shown in figure 7).

[0273] Alternatively, unit 100 is only inserted in the last span 1_n before the receiving station 24 and/or only in some spans $1_1, 1_2, \dots, 1_n$, according to the applications.

Claims

1. Unit(100) comprising a portion of holey optical fibre (12) having a length L_c comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch, said unit being **characterised in that** it also comprises a temperature adjusting device (16) for bringing and maintaining the holey optical fibre (12) at temperature values T selectable in a predetermined interval of temperatures T_x - T_y .
2. Unit (100) according to claim 1, wherein the cladding region (14) of the holey optical fibre portion (12) comprises a first ring of holes around the core region.
3. Unit (100) according to claim 2, wherein the holes of said first ring have a mean diameter d and are spaced from one another by a mean pitch Λ .
4. Unit (100) according to claim 3, wherein the d/Λ ratio is more than 0.7.
5. Unit (100) according to any one of the claims 1 to 4, wherein, for compensating chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values, in a reconfigurable manner at a preselected wavelength λ , the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y are selected so that at the preselected wavelength λ , the holey optical fibre (12) has such values of the chromatic dispersion coefficient $D_c(T)$ in function of the temperature that, as temperature T varies between the value T_x and the value T_y , the following relation $D_t \cdot L_t = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in said predetermined interval of values.
6. Unit (100) according to any one of the claims 1 to 5, wherein, to compensate at a preselected wavelength λ and at a preselected temperature T_z comprised in the interval T_x - T_y , a predetermined value of chromatic dispersion slope s_t and a predetermined value of chromatic dispersion $D_t \cdot L_t$, the hole diameter and pitch, the length L_c and the interval of temperature T_x - T_y are selected so that at the preselected wavelength λ , the holey optical fibre (12) has such values of the chromatic dispersion slope $s_c(T)$ and of the chromatic dispersion coefficient $D_c(T)$ in function of the temperature, as to substantially satisfy the following relations at the temperature T_z

$$D_t/s_t = D_c(T_z)/s_c(T_z) \text{ and } D_t \cdot L_t = - D_c(T_z) \cdot L_c.$$
7. Unit (100) according to any one of the claims 1 to 4, comprising a second portion of holey optical fibre (12') having a predetermined length $L_{c'}$ comprising a core region (13') and a cladding region (14'), said cladding region (14') comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch.
8. Unit (100) according to claim 7, wherein the temperature adjusting device (16) is also suitable for bringing and maintaining the second holey optical fibre (12') at temperature values T' selectable in a second predetermined interval of temperatures T_x' - T_y' .
9. Unit (100) according to claim 8, wherein, for compensating in a reconfigurable manner at the preselected wavelength λ , chromatic dispersion values $D_t \cdot L_t$ comprised in a predetermined interval of values, the hole diameter and pitch of the holes of the first and second holey optical fibre (12, 12'), the lengths L_c and $L_{c'}$, and the intervals of

temperature T_x - T_y and T_x' - T_y' are selected so that at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$, in function of the temperature that, as temperatures T , T' vary, in a predetermined manner, between the value T_x and the value T_y , and respectively, between the value T_x' and T_y' , the following relation (K) is substantially satisfied

$$D_t \cdot L_t = - [D_c(T) \cdot L_c + D_c(T') \cdot L_{c'}]$$

for all values of chromatic dispersion $D_t \cdot L_t$ comprised in said predetermined interval of values.

10. Unit (100) according to claim 9, wherein, to compensate at the preselected wavelength λ and as temperatures T , T' vary, also a predetermined ratio D_t/st between the chromatic dispersion coefficient D_t and a chromatic dispersion slope st , the hole diameter and pitch of the first and second holey fibres (12, 12'), the lengths L_c and $L_{c'}$ and the intervals of temperature T_x - T_y and T_x' - T_y' are also selected so that, at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$ in function of temperatures T and T' that, as the temperatures T , T' vary in said predetermined manner between the value T_x and the value T_y and, respectively, between the value T_x' and the value T_y' , also the following relation (J) is substantially satisfied

$$\frac{D_t}{st} = \frac{\frac{D_c(T)}{sc(T)} \cdot L_c + \frac{D_c(T')}{sc(T')} \cdot L_{c'}}{L_c + L_{c'}}.$$

11. Unit (100) according to claim 9, wherein, for compensating at the preselected wavelength λ and as temperatures T , T' vary, also values, comprised in a preselected interval of values, of a D_t/st ratio between the chromatic dispersion coefficient D_t and a chromatic dispersion slope st , the hole diameter and pitch of the first and second holey fibre (12, 12'), the lengths L_c and $L_{c'}$ and the intervals of temperature T_x - T_y and T_x' - T_y' are also selected so that, at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$ in function of the temperatures T and T' that, as the temperatures T , T' vary in a predetermined manner between the value T_x and the value T_y and, respectively, between the value T_x' and the value T_y' , also the following relation (J) is substantially satisfied

$$\frac{D_t}{st} = \frac{\frac{D_c(T)}{sc(T)} \cdot L_c + \frac{D_c(T')}{sc(T')} \cdot L_{c'}}{L_c + L_{c'}}.$$

for all values of the D_t/st ratio comprised in said preselected interval of values.

12. Unit (100) according to any of claim 7 to 11, wherein, the cladding region (14') of the second holey optical fibre (12') defines a first ring of holes around the core region (13').
13. Unit (100) according to claim 12, wherein the holes of said first ring have a mean diameter d' and are spaced from one another by a mean pitch Λ' .
14. Unit (100) according to claim 3 and 13, wherein the d/Λ ratio of the first holey optical fibre (12) and the d'/Λ' ratio of the second holey optical fibre (12') are different from each another.
15. An optical communication line (1) comprising
- * a portion of optical transmission fibre (10) having a length L_t and a chromatic dispersion coefficient D_t at a wavelength λ ; and
 - * a unit (100) comprising, in turn, a portion of holey optical fibre (12) having a predetermined length L_c and comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch,

characterised in that

- said unit (100) also comprises a temperature adjusting device (16) for bringing and maintaining the holey optical fibre (12) at a temperature value T_z selectable in a predetermined interval of temperatures T_x - T_y ; and

in that

- the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the holey optical fibre (12) has such value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , as to compensate the chromatic dispersion of the optical transmission fibre portion (10).

16. Line (1) according to claim 15, wherein the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the chromatic dispersion coefficient $D_c(T_z)$ has such value as to substantially satisfy the following relation $D_t \cdot L_t = - D_c(T_z) \cdot L_c$.

17. Line (1) according to claim 15 or 16, wherein

- the portion of optical transmission fibre (10), at wavelength λ , also has a chromatic dispersion slope s_t and
- in the unit (100), the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperature T_x - T_y are also selected so that the holey optical fibre (12) has such value of the chromatic dispersion slope $s_c(T_z)$ and such value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , that also the following relation $D_t/s_t = D_c(T_z)/s_c(T_z)$ is substantially satisfied, so as to substantially compensate also the chromatic dispersion slope of the optical transmission fibre portion (10).

18. Line (1) according to any one of the claims 15 to 17, wherein the portion of optical transmission fibre (10) has a chromatic dispersion $D_t \cdot L_t$ variable in a predetermined interval of values, and the hole diameter and pitch, the length L_c and the interval of temperatures T_x - T_y are selected so that at the preselected wavelength λ , the holey optical fibre (12) has such values of the chromatic dispersion coefficient $D_c(T)$ in function of the temperature that, as temperature T varies between the value T_x and the value T_y , the following relation $D_t \cdot L_t = - D_c(T) \cdot L_c$ is substantially satisfied for all chromatic dispersion values $D_t \cdot L_t$ comprised in said predetermined interval of values.

19. Line (1) according to claim 15, wherein the unit (100) also comprises a second portion of holey optical fibre (12') having a predetermined length $L_{c'}$ comprising a core region (13') and a cladding region (14'), said cladding region (14') comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch.

20. Line (1) according to claim 19, wherein the temperature adjusting device (16) is also suitable for bringing and maintaining the second holey optical fibre (12') at a temperature value $T_{z'}$ selectable in a second, predetermined interval of temperatures $T_{x'}$ - $T_{y'}$.

21. Line (1) according to claim 20, wherein for compensating at the preselected wavelength λ , the chromatic dispersion $D_t \cdot L_t$ of the optical transmission fibre portion (10), the hole diameter and pitch of the first and second holey fibres (12, 12'), the lengths L_c and $L_{c'}$, the values of temperature T_z and $T_{z'}$ and the intervals of temperature T_x - T_y and $T_{x'}$ - $T_{y'}$ are selected so that at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion coefficient $D_c(T_z)$ and, respectively, $D_c(T_{z'})$ that the following relation is substantially satisfied

$$D_t \cdot L_t = - [D_c(T_z) \cdot L_c + D_c(T_{z'}) \cdot L_{c'}].$$

22. Line (1) according to claim 21, wherein

- the optical transmission fibre portion (10) has, at the preselected wavelength λ , also a slope of the chromatic dispersion s_t , and
- in the unit (100), the hole diameter and pitch of the first and second holey fibres (12, 12'), the lengths L_c and $L_{c'}$, the values of temperature T_z and $T_{z'}$ and the intervals of temperature T_x - T_y and $T_{x'}$ - $T_{y'}$ are also selected so that at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion slope $s_c(T_z)$ and, respectively, $s_c(T_{z'})$, and such values of the chromatic dispersion

coefficient $D_c(T_z)$ and, respectively, $D_c(T_z')$, that also the following relation is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{D_c(T_z)}{sc(T_z)} \cdot L_c + \frac{D_c(T_z')}{sc(T_z')} \cdot L_{c'}}{L_c + L_{c'}}$$

so as to compensate, at the preselected wavelength λ , also the chromatic dispersion slope st of the optical transmission fibre portion (10).

23. Line (1) according to claim 20, 21 and 22, wherein the optical transmission fibre portion (10) has also a chromatic dispersion $Dt \cdot Lt$ variable in a predetermined interval of values, and the hole diameter and pitch of the first and second holey fibres (12, 12'), the lengths L_c and $L_{c'}$, and the intervals of temperature T_x - T_y and T_x' - T_y' are selected so that at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$, as the temperatures T , T' vary, in a predetermined manner, between the values T_x and T_y , and respectively, T_x' and T_y' , that the following relation (K) is substantially satisfied

$$Dt \cdot Lt = - [D_c(T) \cdot L_c + D_c(T') \cdot L_{c'}]$$

for all values of chromatic dispersion $Dt \cdot Lt$ comprised in the predetermined interval of values.

24. Line (1) according to claim 23, wherein the optical transmission fibre portion (10) also has a Dt/st ratio variable in a preselected interval of values, and the hole diameter and pitch of the first and second holey fibres (12, 12'), the lengths L_c and $L_{c'}$ and the intervals of temperature T_x - T_y and T_x' - T_y' are also selected so that, at the preselected wavelength λ , the first and the second holey optical fibres (12, 12') have such values of the chromatic dispersion slope $sc(T)$ and, respectively, $sc(T')$ and such values of the chromatic dispersion coefficient $D_c(T)$ and, respectively, $D_c(T')$ that, as the temperatures T , T' vary in said predetermined manner between the value T_x and the value T_y and, respectively, between the value T_x' and the value T_y' , also the following relation (J) is substantially satisfied

$$\frac{Dt}{st} = \frac{\frac{D_c(T)}{sc(T)} \cdot L_c + \frac{D_c(T')}{sc(T')} \cdot L_{c'}}{L_c + L_{c'}}$$

for all values of the Dt/st ratio comprised in said preselected interval of values.

25. An optical communication system (20) comprising

- * a transmitting (22) suitable for providing an optical signal having a signal wavelength λ ;
- * an optical communication line (1), optically connected to said transmitting station (22), for transmitting said optical signal, said line (1) comprising at least one portion of optical transmission fibre (10), having a length L_t and a chromatic dispersion coefficient Dt at wavelength λ , and a unit (100) comprising, in turn, a portion of holey optical fibre (12) having a predetermined length L_c and comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch,
- * a receiving station (24), optically connected to said optical communication line (1), for receiving said optical signal,

characterised in that

- said unit (100) also comprises a temperature adjusting device (16) for bringing and maintaining the holey optical fibre (12) at a temperature value T_z selectable in a predetermined interval of temperatures T_x - T_y ; and
- in that**
- the hole diameter and pitch, the length L_c , the temperature value T_z and the interval of temperatures T_x - T_y are selected so that the holey optical fibre (12) has such value of the chromatic dispersion coefficient $D_c(T_z)$ at the preselected wavelength λ and at the temperature value T_z , as to compensate the chromatic dispersion of the optical transmission fibre portion (10).

26. Use, for compensating the chromatic dispersion in a reconfigurable manner, of a unit (100) comprising a portion of holey optical fibre (12) having a length L_c comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch, said unit being **characterised in that** it also comprises a temperature adjusting device (16) for bringing and maintaining the holey optical fibre (12) at temperature values T selectable in a predetermined interval of temperatures T_x - T_y so that the holey optical fibre (12) takes desired chromatic dispersion values $D_c(T)$.

27. Method for compensating chromatic dispersion in a reconfigurable manner, comprising the steps of

- a) providing a holey optical fibre (12) having a length L_c and comprising a core region (13) and a cladding region (14), said cladding region (14) comprising, in turn, a plurality of holes passing through it longitudinally, said holes having a respective diameter and being spaced, two by two, according to a respective pitch;
- b) bringing and maintaining said holey optical fibre (12) at a temperature T selectable in a predetermined interval of temperatures T_x - T_y so that the holey optical fibre (12) has a desired chromatic dispersion value $D_c(T)$.

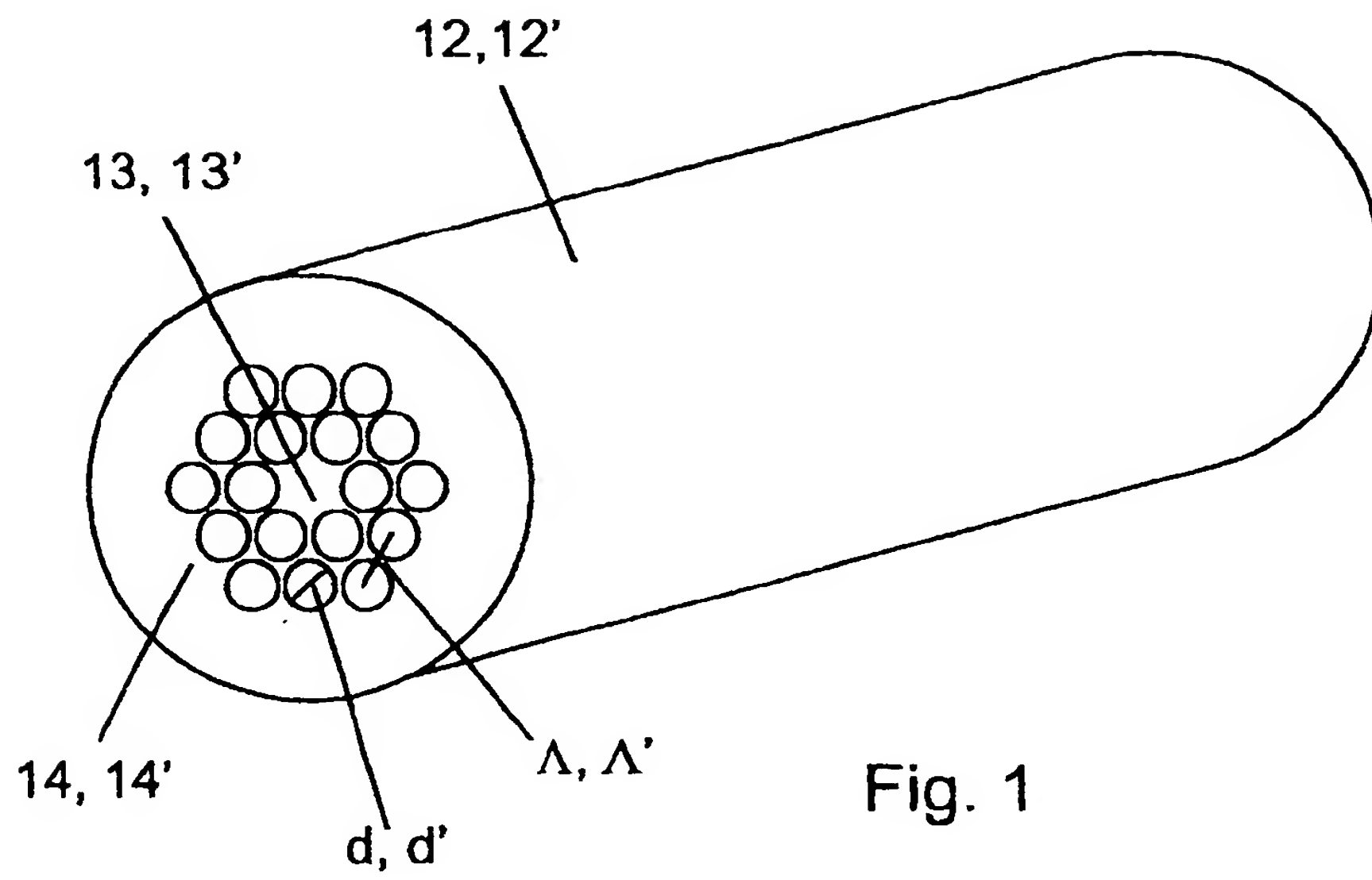


Fig. 1

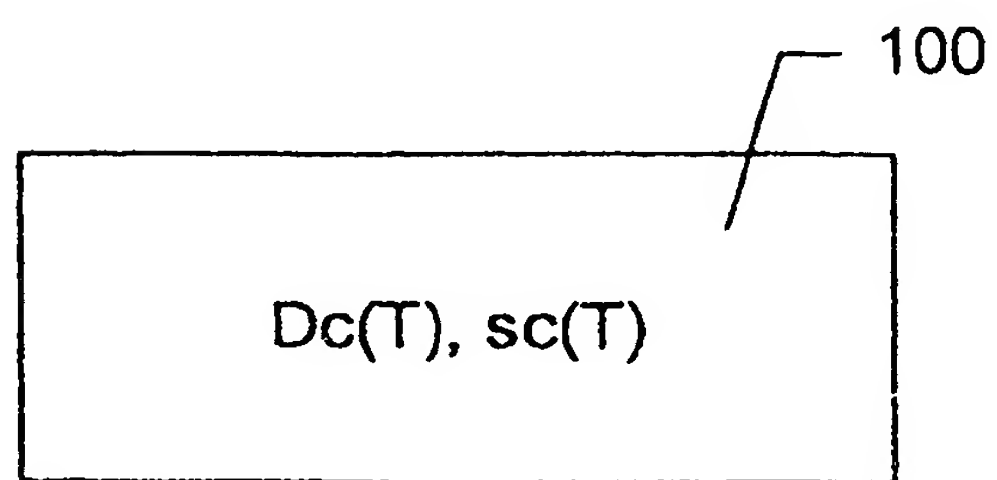


Fig. 2

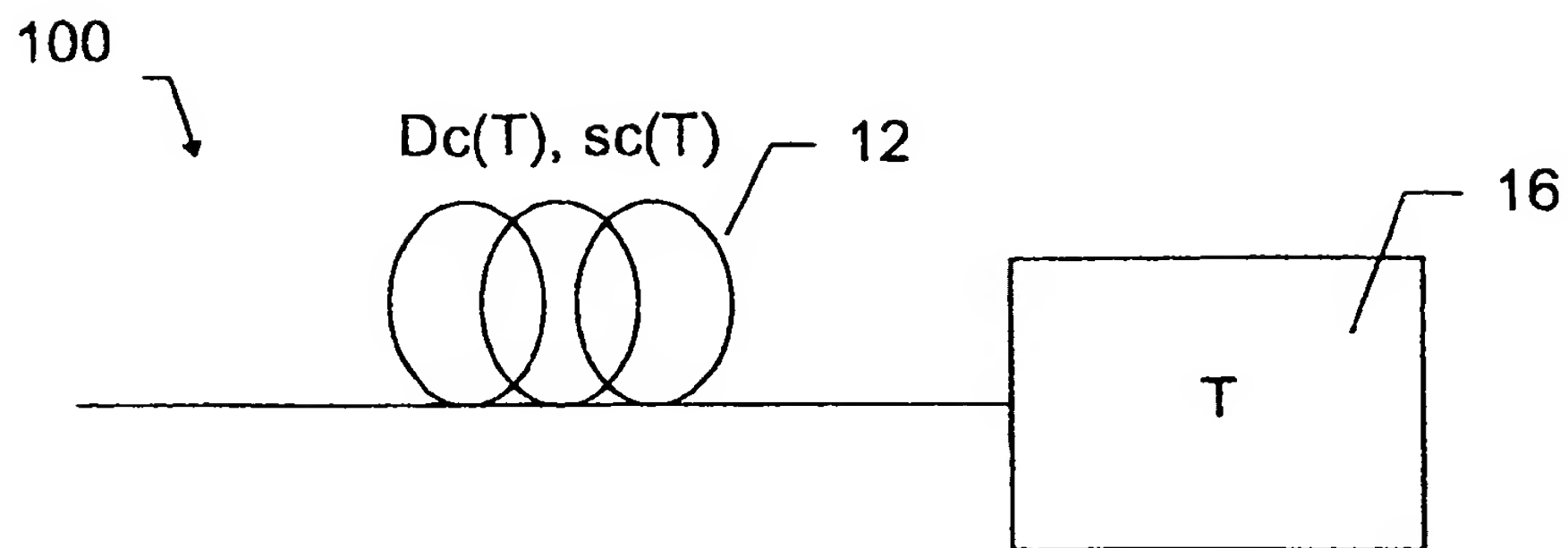


Fig. 3a

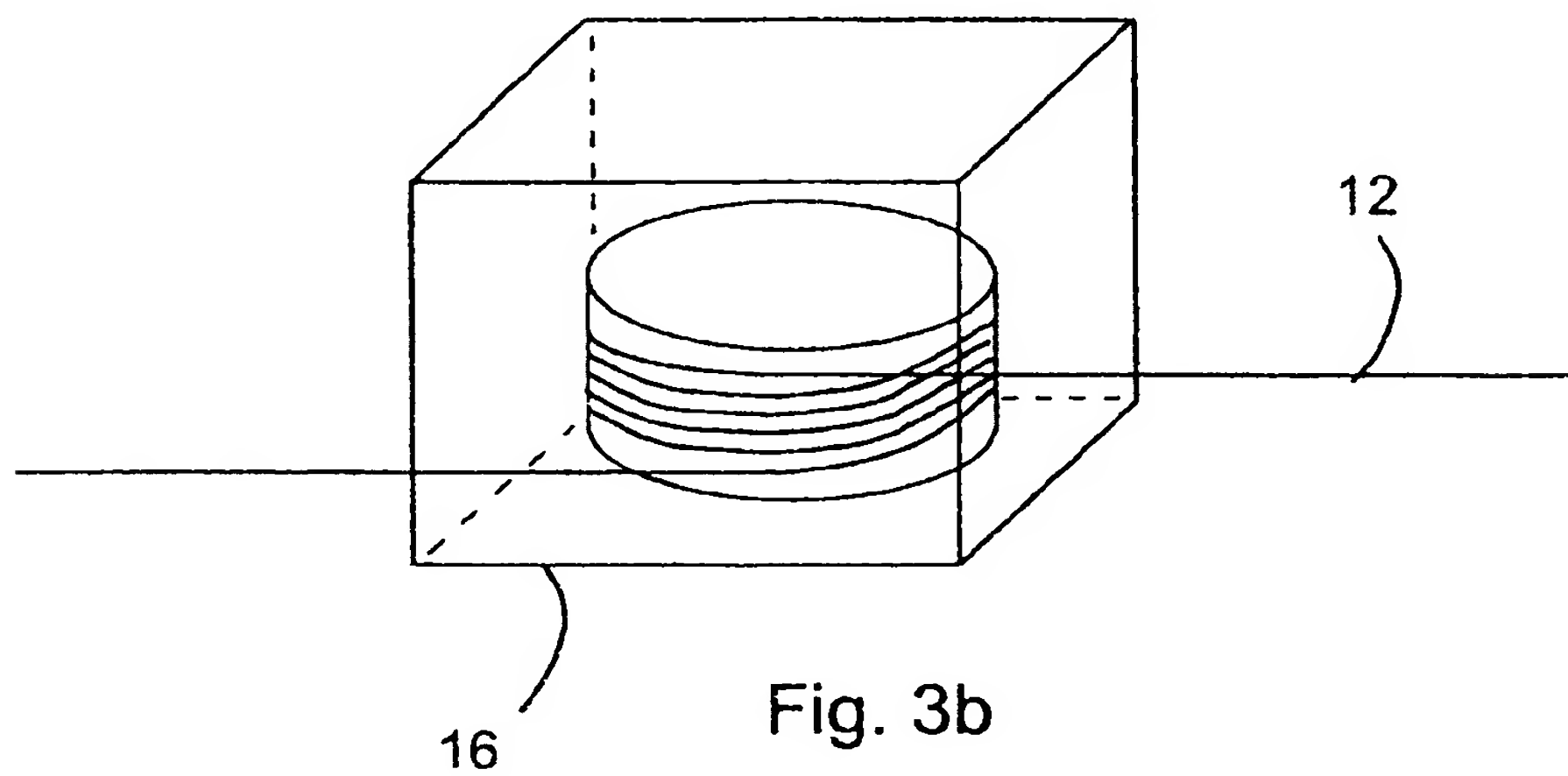


Fig. 3b

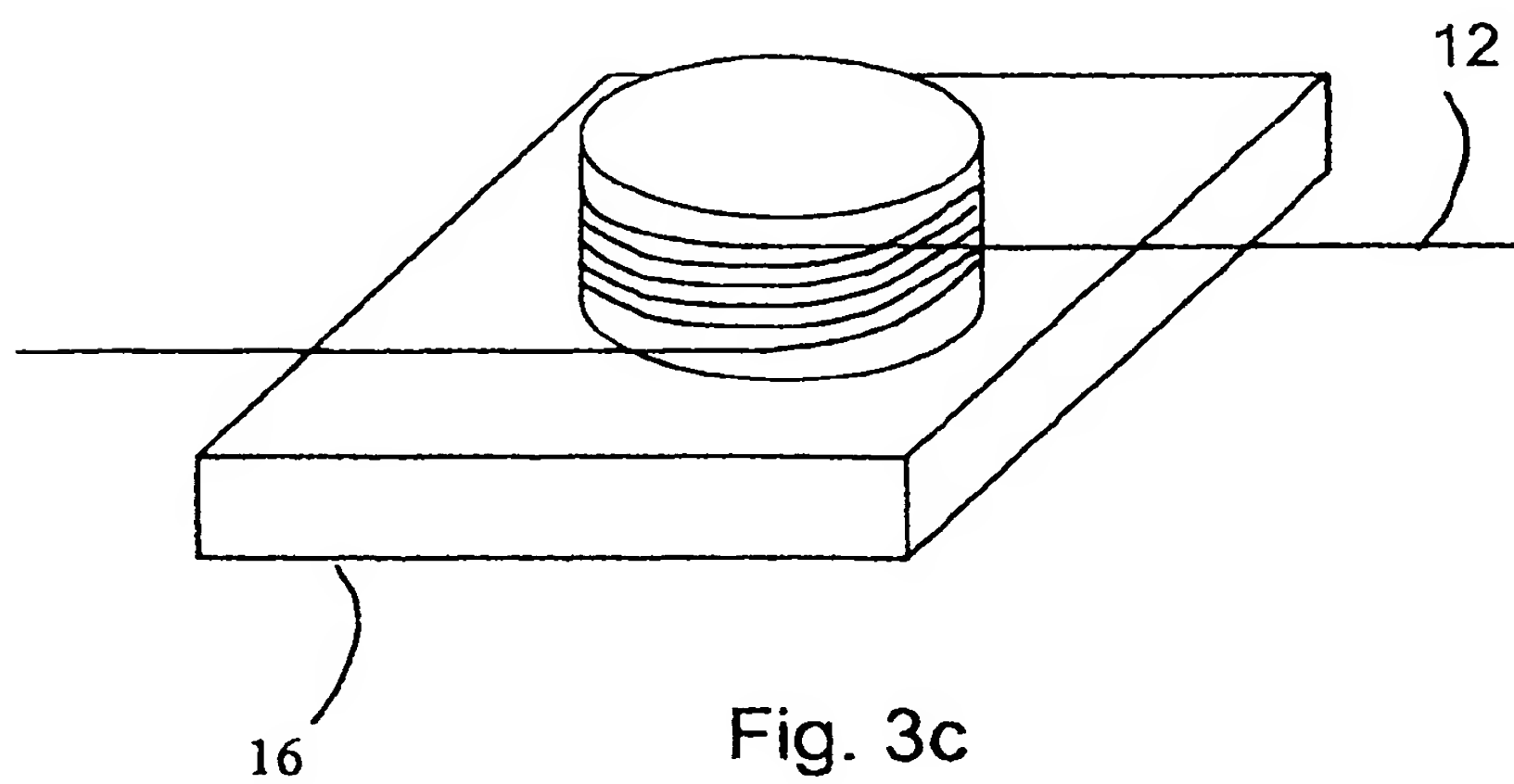


Fig. 3c

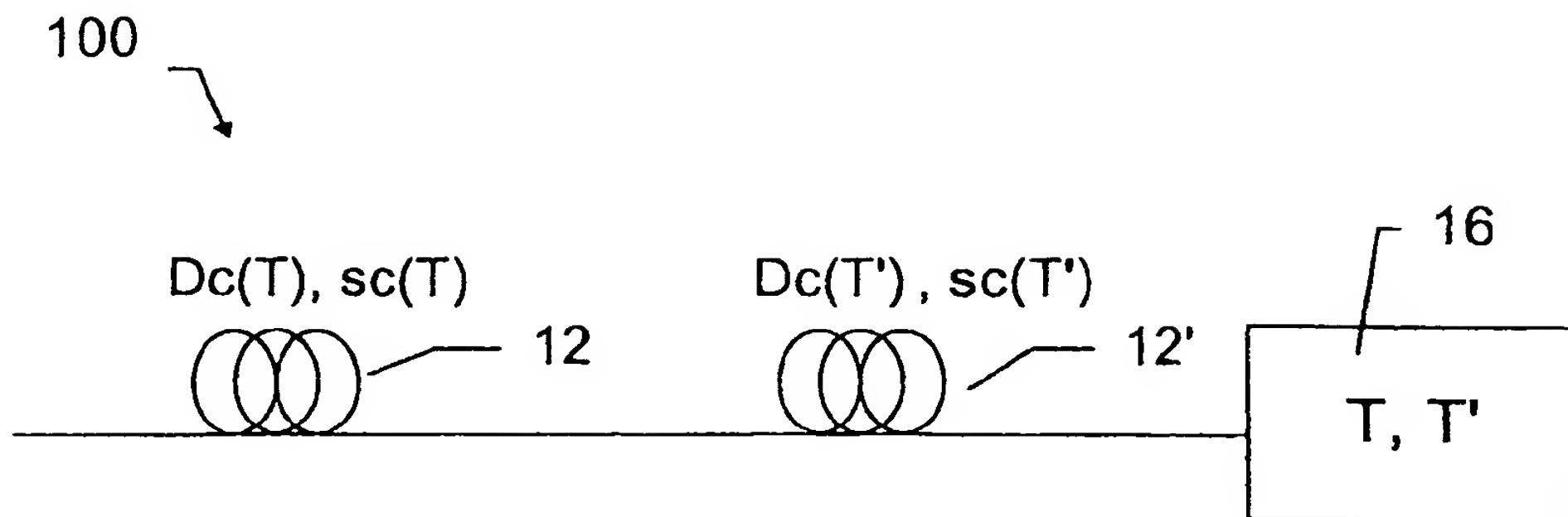


Fig. 4

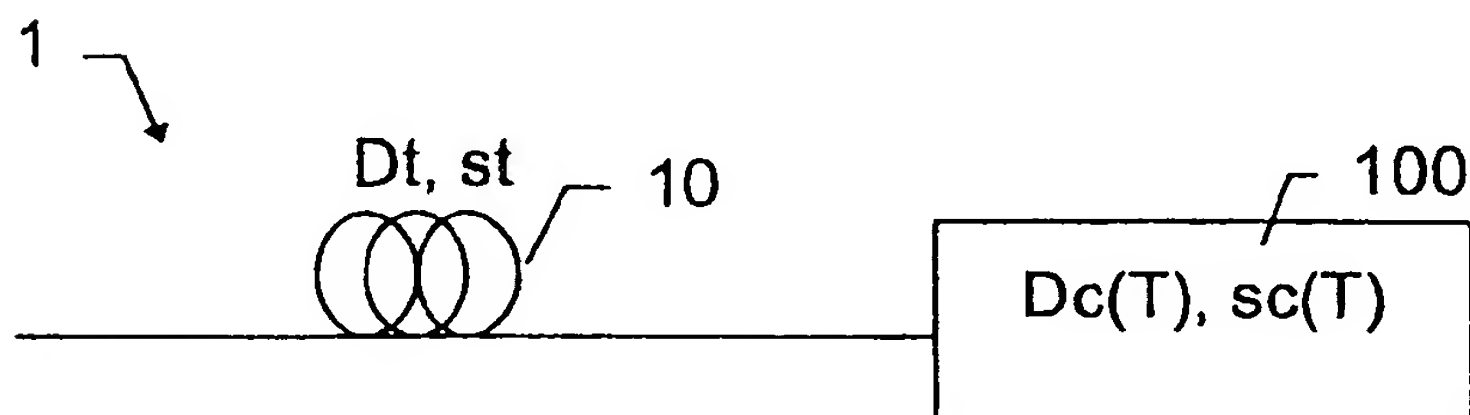


Fig. 5

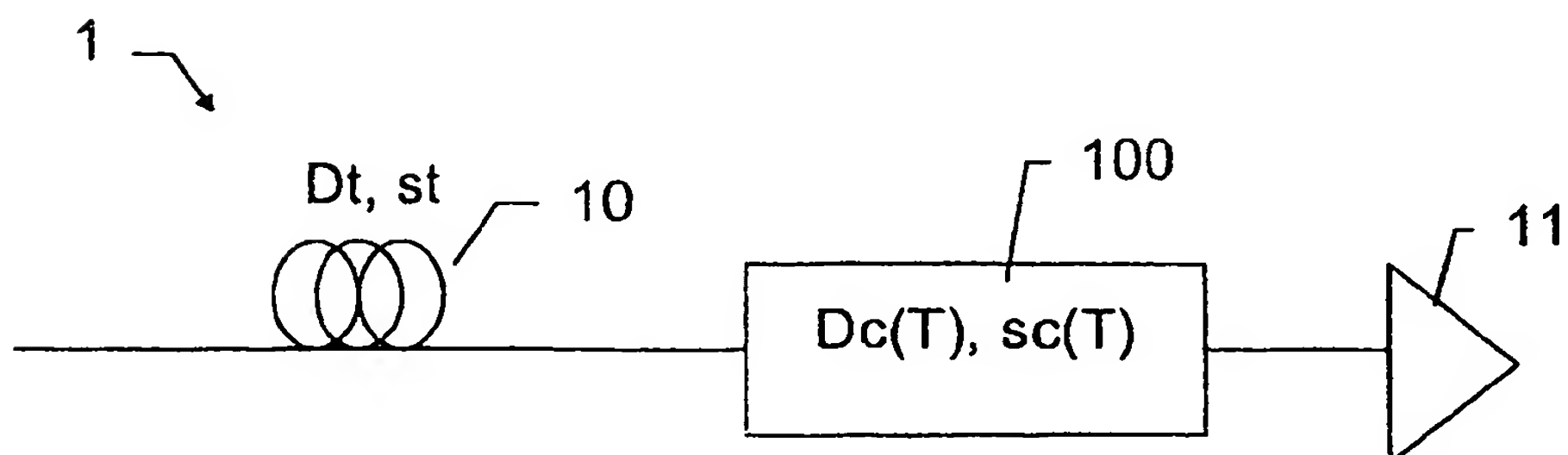


Fig. 6

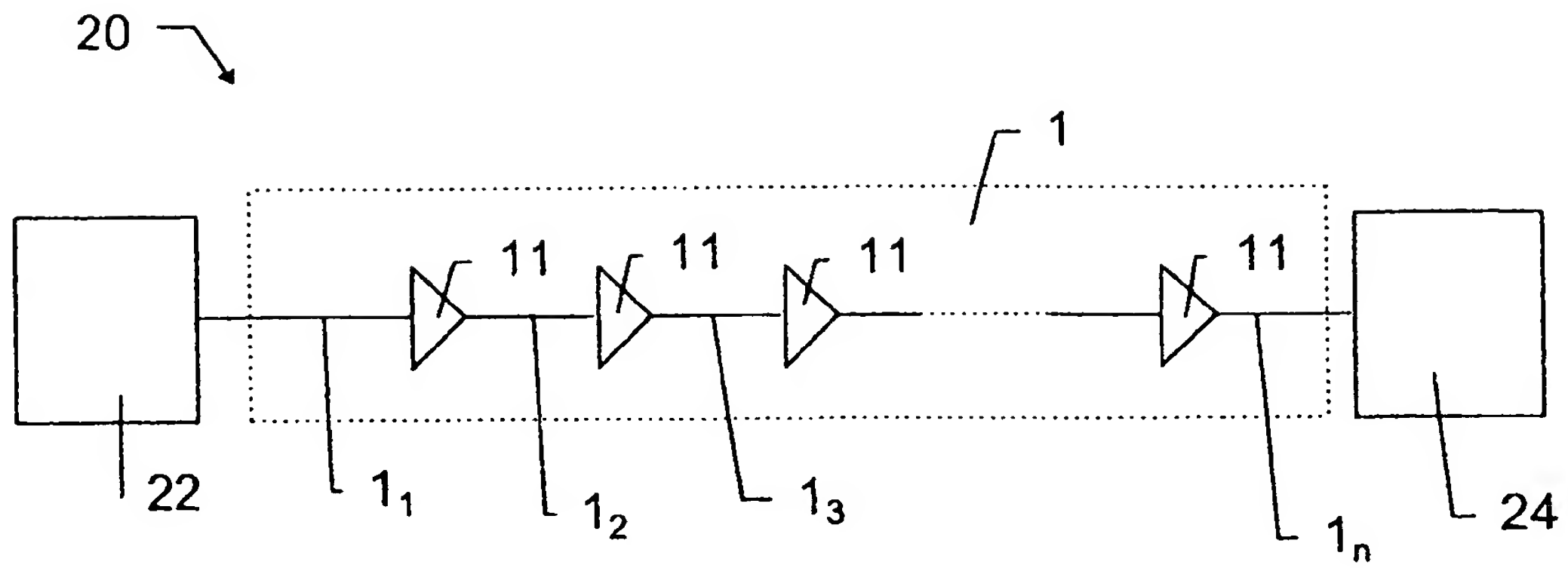


Fig. 7

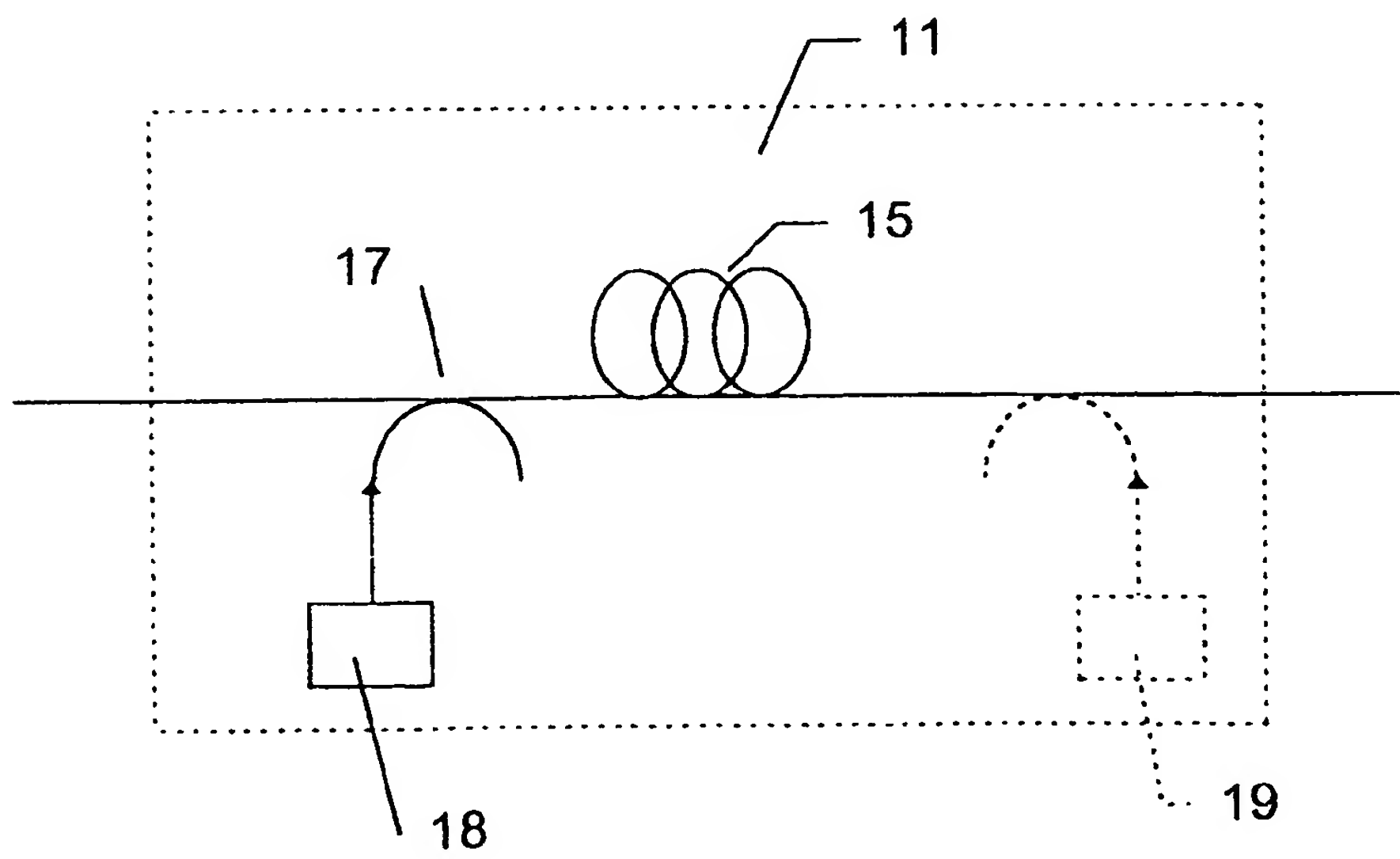


Fig. 8

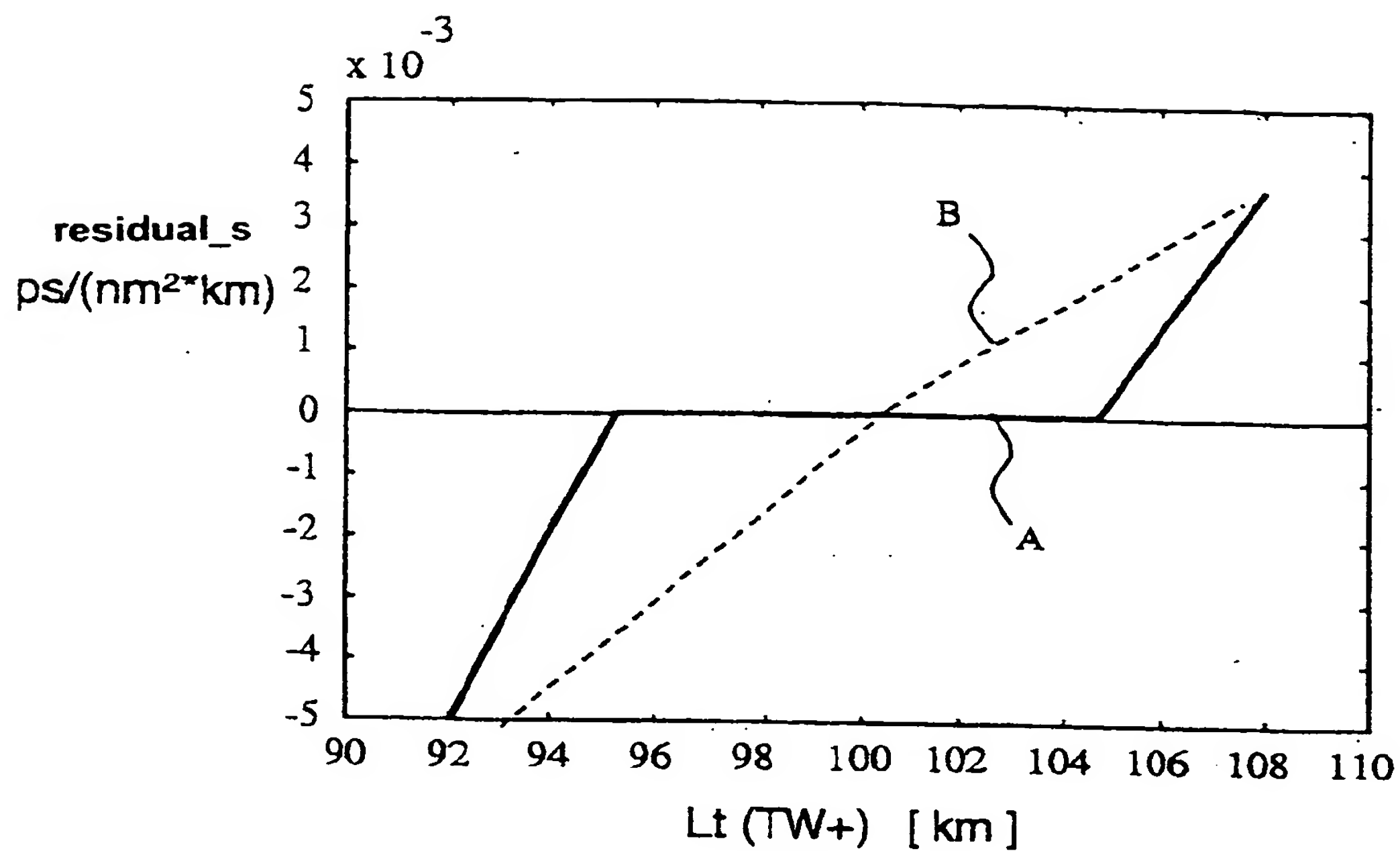


Fig. 9

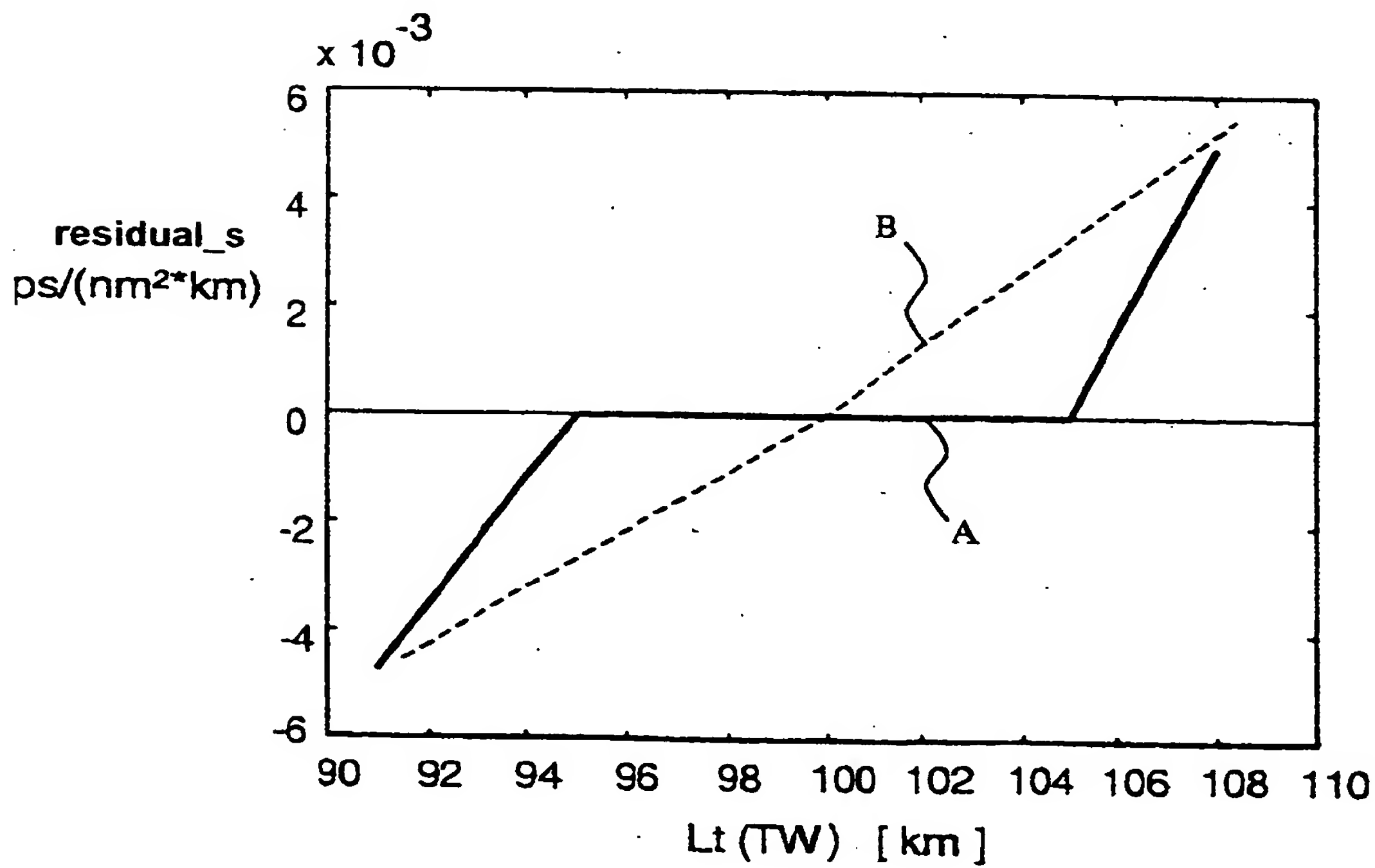


Fig. 10

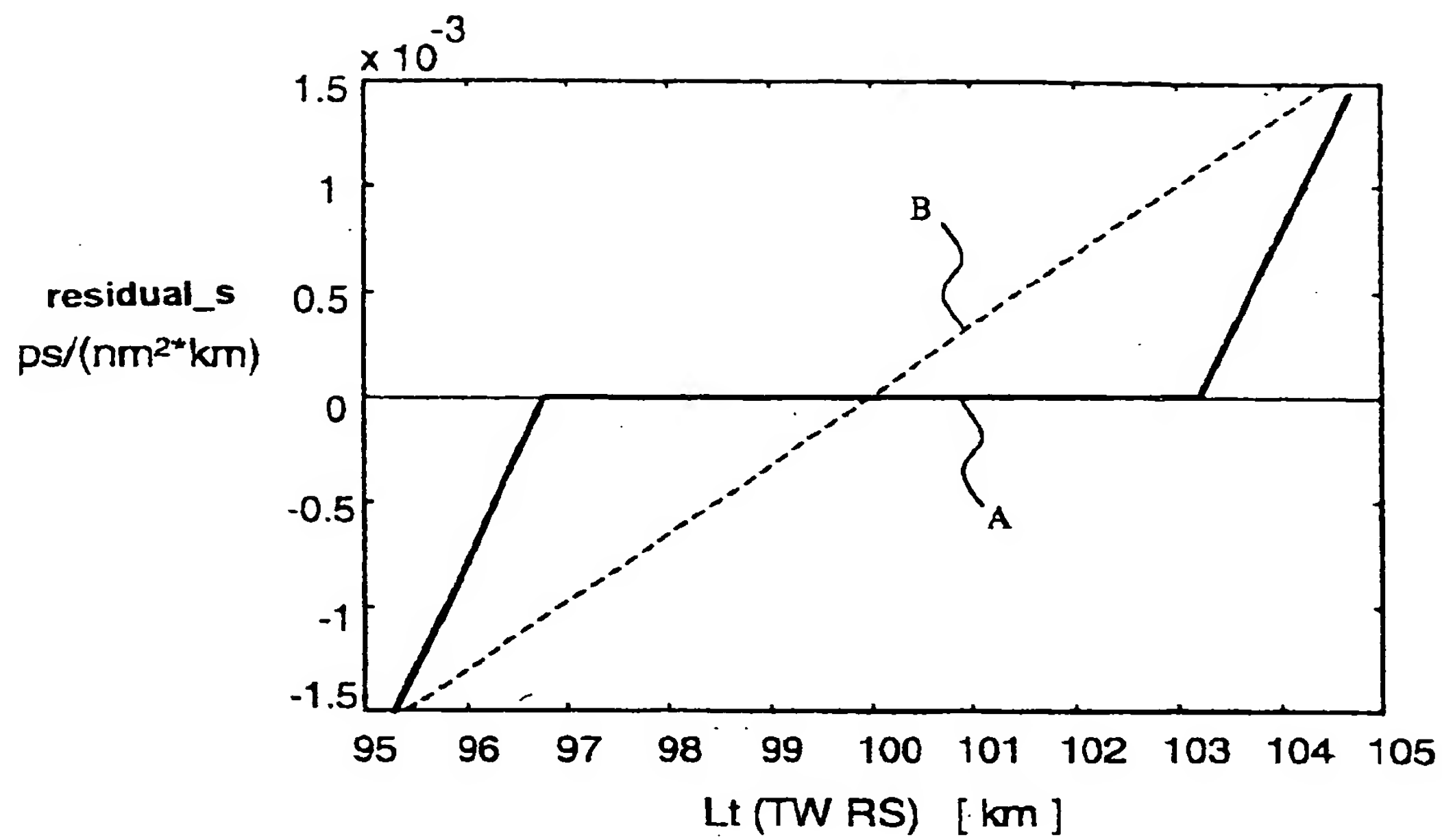


Fig. 11

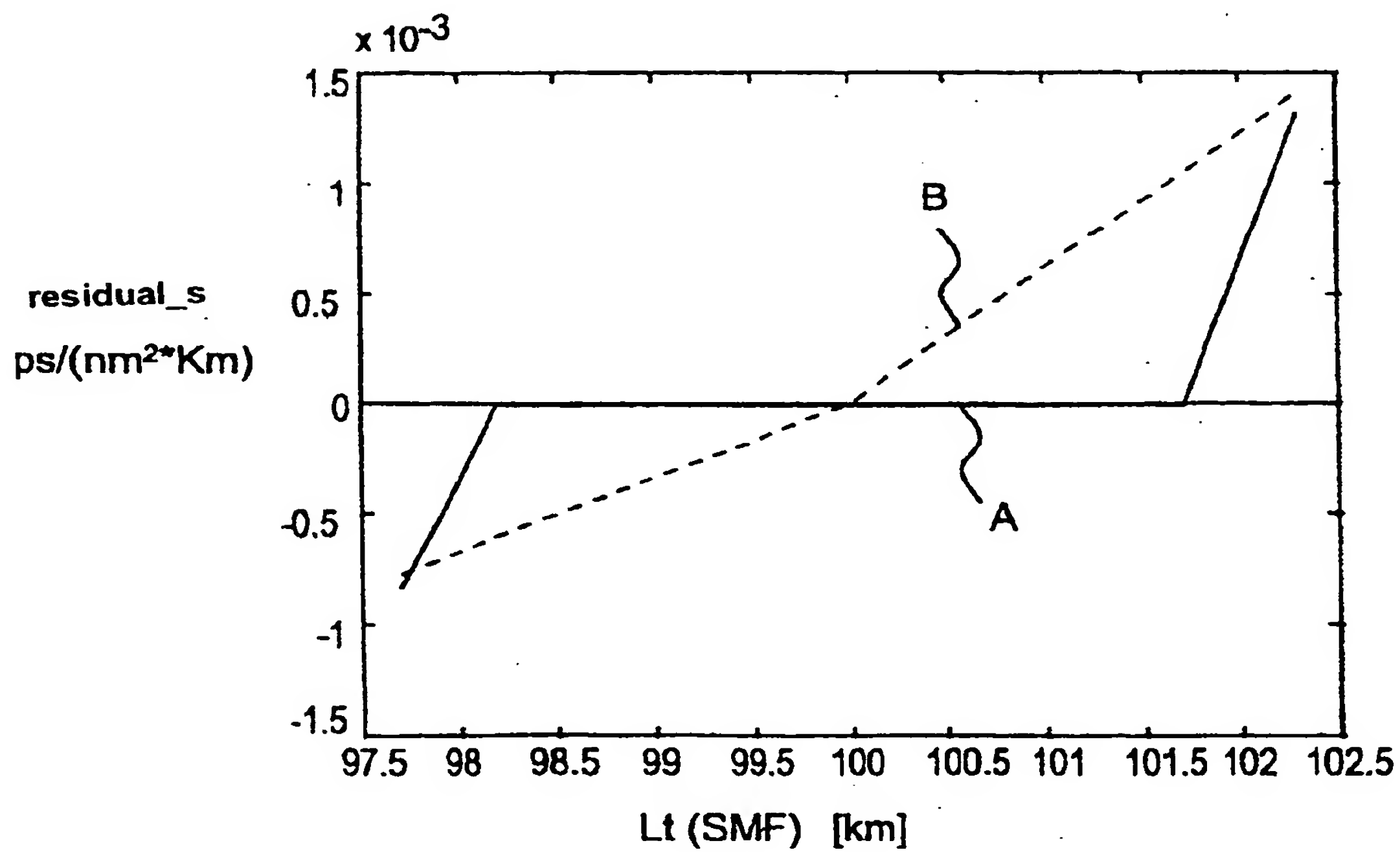


Fig. 12



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 20 2513

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	ABRAMOV A A ET AL: "ELECTRICALLY TUNABLE EFFICIENT BROAD-BAND FIBER FILTER" IEEE PHOTONICS TECHNOLOGY LETTERS, IEEE INC. NEW YORK, US, vol. 11, no. 4, April 1999 (1999-04), pages 445-447, XP000830088 ISSN: 1041-1135 * the whole document *	1-8, 12-14	G02B6/16 C03B37/075 G02B6/12
A	BIRKS T A ET AL: "DISPERSION COMPENSATION USING SINGLE-MATERIAL FIBERS" IEEE PHOTONICS TECHNOLOGY LETTERS, IEEE INC. NEW YORK, US, vol. 11, no. 6, June 1999 (1999-06), pages 674-676, XP000835430 ISSN: 1041-1135 * page 674; figures 1-3 *	1-5,15, 25-27	
A,D	EGGLETON B J ET AL: "TUNABLE DISPERSION COMPENSATION IN A160-GB/S TDM SYSTEM BY A VOLTAGE CONTROLLED CHIRPED FIBER BRAGG GRATING" IEEE PHOTONICS TECHNOLOGY LETTERS, IEEE INC. NEW YORK, US, vol. 12, no. 8, August 2000 (2000-08), pages 1022-1024, XP000968549 ISSN: 1041-1135 * page 1022 - page 1023 *	1,5,15, 25-27	<div>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</div> <div>G02B C03B</div>
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 4 December 2001	Examiner von Moers, F
CATEGORY OF CITED DOCUMENTS		<div>T : theory or principle underlying the invention</div> <div>E : earlier patent document, but published on, or after the filing date</div> <div>D : document cited in the application</div> <div>I : document cited for other reasons</div> <div>& : member of the same patent family, corresponding document</div>	
<div>X : particularly relevant if taken alone</div> <div>Y : particularly relevant if combined with another document of the same category</div> <div>A : technological background</div> <div>O : non written disclosure</div> <div>P : intermediate document</div>			

EPD FORM 1523 (02-02) (F04C01)